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ANALYSIS OF AUSTRALIAN RAINFALL AND RAINDAY DATA WITH RESPECT TO CLIMATIC VARIABILITY AND CHANGE

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PREFACE

Predictions by general circulation models of change in rainfall rates over Australia under the double carbon dioxide scenario are conflicting. It will be sometime before the quality of these predictions improve. One indicator, if change is occurring, is the rainfall data that we are currently recording and the evaluation of its behaviour over time. This report presents the results of statistical analysis of annual and monthly rainfall, annual and monthly number of raindays and annual maximum daily rainfall for between 50 and 69 rainfall stations around Australia. The annual and monthly time series are analysed for trend or change in mean value. Graphical plots of rainfall and rainday data indicate cyclic variations. Statistical analysis of annual rainfall and annual maximum daily rainfall do not indicate any change. But about a third of the rainfall stations indicate changes in the winter rainfall and this implies that the rainfall pattern within a year has changed for these stations. From the analysis of rainday data, a large number of stations indicate change but the change took place before 1960 in most cases. Hence, one can conclude that there is no conclusive evidence of a recent climate change within the analysed rainfall and rainday data.

1. INTRODUCTION

In recent years, there has been growing concern about the enhanced greenhouse effect on world climate. Several studies, using general circulation models (GCMs), give different and sometimes conflicting predictions for future climate under doubled carbon dioxide conditions (Schlesinger and Mitchell, 1987; Mitchell et al, 1989). With respect to changes in rainfall rates, Zillman (1989) shows that the predicted changes from five GCMs range from -2 mm/day to +2 mm/day for the summer period (DJF) at the same site (Central Australia). The discrepancies in the model predictions are mainly attributed to the different ways in which the physical process are formulated in different GCMs. Also, the present model predictions are not very reliable because of the primitive way the cloud dynamics are modelled and the inadequate coupling of the atmosphere-ocean processes. One measure of the quality of a GCM is its ability to reproduce present climate from present information and in this respect, present GCMs are only marginally successful. Solow (1989) mentions three types of problems with modelling climate. Firstly, there are scientific uncertainties about the way in which important climate processes operate. For instance, there are fundamental gaps in our understanding of the carbon cycle. Secondly, there are uncertainties about the values of parameters in the GCMs. For example, global temperature is very sensitive to the albedo and any uncertainty about the albedo leads to uncertainty about climate. Thirdly, problems arise from limitations on computing power.

Problems are worse when GCMs are used to predict future climate. Present day GCMs were never intended to be used for longterm prediction. Instead, they were intended to be used as tools for understanding the climate processes and to predict the weather a few days in advance. The work of Trenberth et al (1988) at NCAR in explaining the causes of the 1988 drought after it has occurred is an excellent example of this. While an enormous amount of effort is being directed at improving the GCMs and hence their predictions, it is perhaps relevant to look for evidence of any change in climate from the observed rainfall and rainday records. If evidence of change exists in the recorded data, then it must be determined whether this is man influenced or due to natural variability. One source of information in making such an evaluation is paleorecords from ice cores, tree rings or coral cores.

2. EARLIER STUDIES OF LONGTERM RAINFALL DATA

In a comprehensive review of the recorded data, Ellsaesser et al (1986), claim that the data base for precipitation is not good and that there is comparatively little agreement on the normal level of mean global precipitation. Investigations of long period records for individual regions and geographical regions reveal cyclic variations but no significant long-term trends (Tyson et al, 1975; Hakkarinen and Landsberg, 1981).

Based on precipitation data at 7 stations along the North American Pacific coast with record lengths of 67 to 129 years, McGuirk (1982) found some evidence of periodicities near 20-25 and 2.1 years. In subtropical Africa, 20-30 year cycles are apparent in many records (Nicholson, 1980). The analysis of records from 157 South African stations for the period 1910 to 1970 showed two positive trends and 24 negative trends (Tyson et al, 1975). Tyson et al (1975) also found 16- to 20-year cycles at 62 stations and 10- to 11-year cycles at an additional 30 stations. The analysis of east African rainfall by Rodhe and Virji (1976) found generally below average rainfall in the 1940s and 1950s and above rainfall average in the early 1960s. Only stations in northern Kenya showed an upward trend extending over about 50 years. The increase in rainfall in the late 1950s and early 1960s caused an increase in the level of Lake Victoria. Lamb (1966) argued that this rise in lake level indicated a return to the wetter conditions that appear to have existed before 1895. However, since 1964, rainfall has not been excessive and lake levels appear to be falling (Rodhe and Virji, 1976).

Mooley and Parthasarathy (1984) constructed a 10 year moving average for the Indian monsoon rainfall for the period 1871 to 1978. These showed maxima in 1889 and 1953, abrupt drops to minima in 1899 and 1965 and generally gradual increases elsewhere. Corona (1978, 1979) analyzed (by season) 40 years of monthly rainfall data for northern hemisphere land areas using approximately 1300 stations from the NCAR data archive. For summer rainfall, he noted 20-year cycles with minima in the early 1940s and 1960s and maxima in the late 1950s and at the end of the record (1974). For winter rainfall, there were 30 years of increasing trend following the early 1940s minimum. Gruza and Apasova (1981) performed a detailed analysis of trends in northern hemisphere precipitation (1891-1975), for the months of January and July only, using a 2.5 degree latitude by 2.5 degree longitude grid. From the data (by latitude bands), they concluded that in January there is a background of minor positive trends for the entire period with increases in precipitation in 1940-1946, after which, there is a reduction in 1946-1975 and a sharp increase at the end of the period. In July, the pattern of sign and magnitude of variation in trend, by zones and periods, becomes less coherent.

Using precipitation data from the earliest records to 1970 for Western Europe, Tabony (1981) concluded that:

> "... trends from single stations are unreliable due to

errors associated with exposure and change of site and instrumentation;..."

"... the dense network of stations in London covering a period 1911-1970 reveal no clear urban effects. So homogenized rainfall series produced without regard to urbanization effects are suitable for investigation into climate change;..." and,

"... installation of wind shields on rain gauges to improve collection of snow has caused measured winter precipitation to increase in relation to summer."

After a detailed study, a large number of rainfall records were combined to produce regional series and Tabony's regional decadal mean curves showed prominent peaks during the 1870s in many areas and prominent dips during the 1940s particularly in southern Europe.

Barnett (1985) reviewed existing precipitation trend analysis and found large scale regional coherence in precipitation data with large amplitude oscillations of decadal time scales. He further stated that the land data did not support the concept of a globally coherent signal and the absence of oceanic data made the search for a global signal senseless. For the seven regions with sufficient data for analysis, he found a non-significant decrease over continental US, an even weaker increase for Europe and western Asia, no significant trend for the summer monsoon rainfall of India, a strong decrease over Africa and no trends for other regions (Australia and the Indo-Pacific, Japan and eastern China and southern South America).

From a study of annual flows and stored water in 140 rivers from various parts of the world with record lengths of 40 to 150 years, Yevdjevich (1963) concluded that there is no evidence that the climatic factors as related to water resources have changed significantly in the last 150 years. In a recent study, Kite (1989) analysed long series of lake level data from the USA and Uganda and river flow data from Canada and found no statistical components that could be ascribed to greenhouse induced climatic change.

In Australia, a number of studies have also been carried out and these have conflicting conclusions. Analysis of long-term rainfall series from Victoria and New South Wales (Kraus, 1954) showed a decrease of summer rainfall to a minimum about the turn of the century with fifty years of gradual increase since then. This is in agreement with Deacon (1953), who showed that the summer rainfall over much of the southern part of Australia for the period 1911-1950 was considerably greater than that in the previous 30 years. From an analysis of annual and monthly rainfall totals for 99 stations throughout New South Wales, Cornish (1977) observed an increase in annual and summer rainfall in central New South Wales.

In examining the variation in summer and winter rainfall from 200

widely spread stations in Australia over the 80 year period (1895-1974), Russell (1981) found significant increases in summer rainfall at 42 stations, mostly in southeastern Australia. Only two stations showed significant decreases. In contrast, only seven stations showed significant increases in winter rainfall and five showed significant decreases.

Using a distribution-free CUSUM technique, McGilchrist and Woodyer (1975) found that there was no significant change in the mean value of annual rainfall at Wallgett, New South Wales, for the period 1878 to 1965. Doran and McGilchrist (1983) analysed annual rainfall records for the period 1890 to 1980 at 45 stations, also using the CUSUM technique, and concluded that there was no evidence of continental climate change for Australia. They also said that cyclic patterns of wet and dry periods do occur, but they lie within the bounds expected of randomly behaved phenomena.

Using 180 years of flood stage records at Windsor and 90 years of discharge data at Penrith, Warner (1987) defined alternating flood dominated and drought dominated regimes for the Hawkesbury-Nepean River System. The drought dominated regime periods are 1821-1863 and 1901-1948 and those of flood dominated regimes are 1799-1820, 1864-1900 and 1949 onwards.

Pittock (1975, 1983) analysed 66 years (1913 to 1978) of Australian rainfall data and found an abrupt increase in rainfall circa 1945-46 over most of the continent. He attributes this to a change in climate. Srikanthan and Stewart (1989) analysed the annual rainfall at 80 stations throughout Australia and found that the variations in the parameters for the recent period were within the natural variability of annual rainfall.

The apparent contradiction between the above two analyses (Pittock, 1975; Srikanthan and Stewart, 1989) can be attributed to the different data lengths used in the two studies. If one uses rainfall data covering only one drought dominated period followed by one flood dominated period, an upward trend will be observed most of the time. Pittock's studies used only one drought dominated period followed by a flood dominated period (as defined by Warner above) and consequently an upward trend was observed. The latter study (Srikanthan and Stewart, 1989) used longer records covering, in most cases two flood dominated periods and one drought dominated period. Consequently the variations in the statistics for the recent period (flood dominated regime) were similar to those from the early part of the record.

In this report, annual and monthly rainfall totals, annual and monthly number of raindays and annual maximum daily rainfall were analysed for any trend or change in mean value. Even though there have been many analyses performed on the rainfall totals, we are not aware of any studies of long time series of rainday data or maximum daily rainfall data.

3. RAINFALL AND RAINDAY DATA

The data from the Bureau of Meteorology rainfall stations were examined to obtain a network of stations which had consistent and homogeneous records. Consistency relates to the type and techniques of measurement, the sampling interval and the manner of processing data. Over the years, this has not changed with regard to the measurement of daily rainfall. An 8 inch raingauge is used and readings are taken at 9 am every day. The units of rainfall measurement changed from points to millimetres in 1972, but this should not affect the monthly or annual totals significantly. Recently, at some stations, rainfall has not been recorded on Sundays or public holidays, but again this should not affect the analysis of monthly and annual rainfall totals. Also, the use of daylight saving time in the eastern States should have negligible effect on monthly and annual rainfall totals. Homogeneity relates to the constancy of the measurement site and of its environmental conditions.

A total of 92 stations were initially selected for analysis. Closer examination of the data indicated a number of months of missing data. Missing data were infilled using nearby station data. Arithmetic average of nearby station rainfalls was used for missing months when the mean annual rainfall among them did not vary by not more than 10%. It was not possible to reliably estimate the missing data for 12 of the stations and these were omitted from the analysis. The station history files for the remaining stations were examined to determine changes in instrumentation or location over the period of record. It should be noted that very little information on changes prior to the 1910s is available. Approximately 50% of the stations had been moved. However, this was on average a distance of only a few hundred metres. While no changes in instrumentation had been recorded, there had been changes in the gauge height at a small number of stations. A more significant factor may be changes in the observer. Double mass curves for each site were plotted using adjacent stations. These curves were examined in conjunction with the station history records to determine any deviations in the record which could have resulted from any of the above disturbances. On the basis of this evaluation eleven more stations were omitted from the analysis. This resulted in 69 stations (Table 1) with an average length of record of 110 years. Their locations are shown on Fig 1.

All of the 69 rainfall stations did not have continuous maximum rainfall and rainday data. Stations with only a few missing observations were infilled using data from nearby stations. For rainday data, missing values were infilled as before when data at nearby stations were available. Otherwise, longterm mean values were used. Missing values were not infilled for maximum rainfall because of the large spatial variability in extreme rainfalls. As the interest is in annual maximum rainfall, it was possible to use the data where the missing values occurred either in a low rainfall month or where the total rainfall recorded for the missing month was less than the maximum rainfall record in another month in the same calendar year.

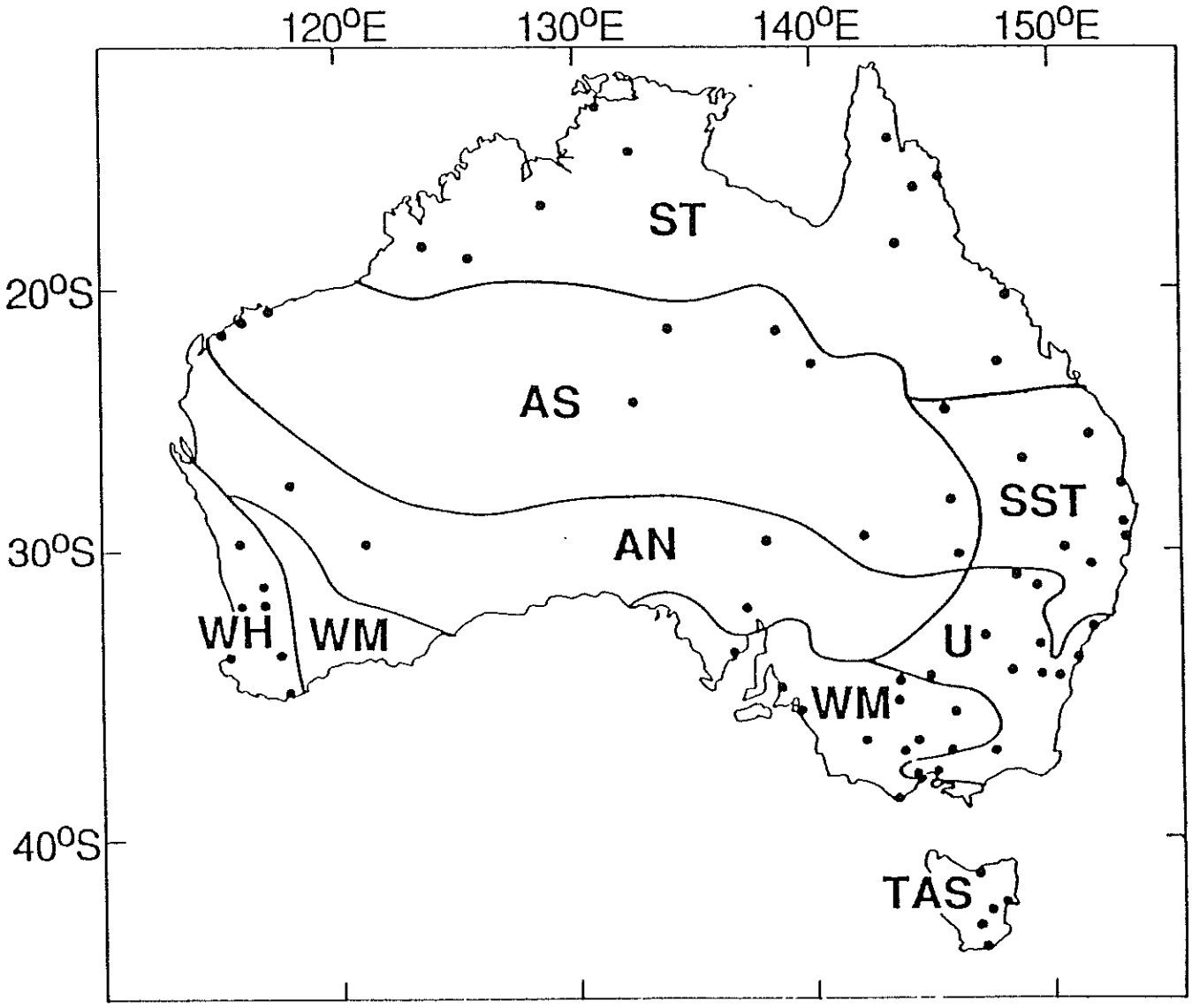

Fig 1 Locations of rainfall stations used in the study.

In the reported study, annual and monthly rainfall from 69 stations, annual and monthly number of raindays from 50 stations and annual maximum daily rainfall from 50 stations were analysed. The length of record varies from about 70 to 140 years. Details of the rainfall stations are given in Table 1. The differences in the number of rainfall stations and the length of records among the three data sets are due to missing observations. The annual parameters of rainfall, rainday and annual maximum daily rainfall are given in Tables 2, 3 and 4 respectively.

4. METHODS OF ANALYSIS

4.1 Time Series Plots

Time series plots enable quick visual detection of any apparent trend or change in mean value in the plotted series. Eleven year moving average and an 11-point Gaussian filter were also used to smooth the series. These have also been plotted for visual inspection. Since trends from single stations may be unreliable, due to errors associated with exposure, change of site and instrumentation, the regional mean series were also formed and plotted. Australia was divided into eight climatic regions based on the seasonal rainfall pattern (Bureau of Meteorology, 1975) and these are shown in Fig 1. The number of rainfall stations in each region is given in Table 5.

For each region, a regional mean series was formed by first standardizing individual station data to have zero mean and unit variance and then finding the average of the standardized series.

$$X_{im} = (x_{im} - \bar{x}_m)/s_m \qquad (1)$$

$$Y_i = (1/k)\sum_{m=1}^{k} X_{im} \qquad (2)$$

where x_{im} - actual value in year i at station m

$\bar{x}_m$ - mean value at station m

s_m - standard deviation at station m

X_{im} - standardized value in year i at station m

Y_i - region mean value for year i

k - number of stations in a given region

4.2 Statistical Tests

The following six statistical tests were applied to the three data sets.

1. Mann-Kendall rank correlation
2. Spearman rank correlation
3. Cumulative sum test
4. Likelihood ratio test
5. Distribution free CUSUM technique
6. Two-phase regression

The above numbering system is used to refer to the tests in the results provided in Tables 6, 9, 10, 13, 16, 17, and 19.

4.2.1 Mann-Kendall rank correlation

The Mann-Kendall rank correlation statistic, T, is defined as

$$T = 4\sum_{i=1}^{n-1} n_i/[n(n-1)] - 1 \qquad (3)$$

where n_i is the number of observations larger than the i^{th} observation in the series subsequent to its position in the series of n values. The expected value of T is zero and the variance is given by

$$Var(T) = (4n+10)/[(9n(n-1)] \qquad (4)$$

4.2.2 Spearman rank correlation

The Spearman rank order correlation coefficient, r, between the observations x_t in the series and time, t, is used as a basis for the test. One set of ranks gives R_t, the rank of x_t in the series, and the other set T_t being 1, 2, ..., n. The coefficient is computed as

$$r = 1 - 6\sum_{t=1}^{n} (R_t - T_t)^2/(n^3 - n) \qquad (5)$$

The test statistic

$$t = r[(n-2)/(1-r^2)]^{1/2} \qquad (6)$$

is distributed as Student's t with (n-2) degrees of freedom.

4.2.4 Cumulative sums test

The purpose of this test is to detect the existence of a jump in the mean after m observations

$$E(x_t) = \begin{cases} \mu & t = 1, 2, \ldots, m \\ \mu + d & t = m+1, \ldots, n \end{cases} \qquad (7)$$

where μ is the mean value before the jump and d is the jump in the mean value. The basic assumptions of this test are that the observations are independent and normally distributed. The test can still be applied when there are slight departures from normality.

Let $S_o = 0$, $\quad S_k = \sum_{t=1}^{k} (x_t - x) \quad k = 1, 2 \ldots, n$

$$D^2 = \sum_{t=1}^{n} (x_t - x)^2/n$$

$$S_k^* = S_k/D \quad k = 1, 2, \ldots, n$$

The test statistic is

$$Q = \max_{0<k<n} |S_k^*| \qquad (8)$$

Percentage points of the statistic Q are given in Buishand (1982).

4.2.5 Likelihood ratio test

In this test, a new variable, Z_k, is defined in terms of the cumulative departures, S_k as

$$Z_k = [k(n-k)]^{-1/2} S_k/D \qquad (9)$$

The test statistic is

$$W = (n-2)^{1/2} V/(1 - V^2)^{1/2} \qquad (10)$$

where $V = \max_{1<k\leq n-1} |Z_k|$

Percentage points of the statistic W are given in Worsley (1979).

4.2.6 Distribution-free CUSUM technique

The distribution-free CUSUM technique uses estimates of U_t defined by

$$U_t = \sum_{i=1}^{n} g(x_i - \tilde{x}) \qquad (11)$$

where $\tilde{x}$ = sample median
and $g(x) = 1$ if $x \geq 0$
$= -1$ if $x < 0$

The test statistic is $U = \max |U_t|$ and the upper 5% value is $1.92/\sqrt{M}$ where $M=n/2$.

In the above tests, the position of maximum $|S_k^*|$, $|Z_k|$ or $|U_k|$ can be taken as an estimate of the change point m.

4.2.7 Two-phase regression

The two phase regression model (Solow, 1987) is written as

$$x_t = a_o + b_o t + e_t \quad t = 1,2, \ldots, m \qquad (12)$$
$$= a_1 + b_1 t + e_t \quad t = m+1, \ldots, n$$

where a_o, b_o, a_1 and b_1 are regression coefficients and e_t is an independent sequence with zero mean and unknown variance σ^2. The abscissa of the intersection of the two regression lines is

$$c = (a_o - a_1)/(b_1 - b_o) \qquad (13)$$

The null hypothesis $H_o: b_1 - b_o = 0$

Alternative hypothesis $H_1: b_1 - b_o \neq 0$

Because no closed form expression is available for c, it is necessary to search for the likelihood function to find its maximum.

Equation (12) can be rewritten as

$$x_t = a_o + b_o t + b(t-c)I(t) + e_t \qquad (14)$$

where $I(t) = 0$ if $t < c$
$= 1$ if $t \geq c$
and $b = b_1 - b_o$

The likelihood ratio statistic is

$$L = [(S_o - S)/3]/[S/(n-4)] \qquad (15)$$

where S_o is the residual sum of squares from fitting the null model

$$x_t = a_o + b_o t + e_t \qquad (16)$$

and S is the residual sum of squares from fitting the alternative model (16). The asymptotic distribution of L under the null hypothesis of no change is the F distribution with 3 and n-4 degrees of freedom.

5. ANALYSIS OF RAINFALL DATA

5.1 Annual Rainfall Data

The time series, moving average and Gaussian filter plots for regional mean annual rainfall are shown in Figs B1 to B8. The smoothed values were plotted at the centre point of the moving average and the Gaussian series period. Due to a limitation in the graphics package used, the first five values of the annual series are not plotted. High rainfall was observed in the region ST (Fig B1) in the 1970s. In the region SST (Fig B2), high rainfall was observed in the 1890s, distinctly low rainfall from 1910 to 1945 and high rainfall (but not as high as the 1890s) afterwards. In the region U (Fig B3), high rainfall is observed in the periods 1865-1900 and 1945-1985 (of the same order of magnitude). Low rainfall is observed in the middle period. For regions AS (Fig B4) and AN (Fig B5), high rainfall is observed in three periods (1865-1880, 1905-1925 and 1955-1970) and low rainfall in two periods (1880-1905 and 1970 onwards). The latter is not as severe as the former. In region WM, rainfall peaks and troughs occur frequently (Fig B7). The last peak in the 1970s is similar in magnitude to the first one in the 1850s. For the Tasmanian region, high rainfall is observed in the early and latter parts of the record. The last peak is slightly larger than the earlier ones (Fig B8).

Even though we visually observe apparent high and low rainfall periods, none of the first five tests indicated any significant trend or change in the mean value (at the 5% significance level). Test 6 indicated significant changes for three cases only (ST in 1935, WH in 1917 and AS in 1901; see Table 6). Since the percentages of variance explained by the regression lines are less than 6% for both cases, little confidence is placed on the results from this test.

When the statistical tests were applied to individual station data, the number of stations indicating significant trend or change in the mean value, varied from 2 to 12 (Table 7). For the two-phase regression test, only three of the 11 cases have regression equations explaining more than 10% of the variance and hence the outcomes of this test cannot be considered reliable.

For the station data, the number of tests indicating significant trend or change in the mean value are summarised in Table 8.

If it is assumed for this analysis, that we need a significant result in at least three of the six tests applied to each data sequence to indicate change, then six (~9%) stations have significant changes in their record (Table 8).

In addition to the above analysis, annual means were calculated for flood and drought dominated periods given by Warner (1987) and the results are given in Table 9. With the exception of 12 stations, the data exhibit the expected high-low-high pattern.

5.2 Monthly Rainfall Data

The regional mean monthly rainfall time series, moving average and Gaussian filter plots (Figs B9 to B104) were examined visually. As in the annual case, most months exhibited alternating periods of high and low rainfalls. When the statistical tests were applied, only a few cases indicated significant trend or change in mean value at the 5% level. Only the months and regions indicating significant change are given in Table 10.

Table 10 shows only three cases, region WM (January), region AN (February) and region TAS (November), having three of the six tests indicating significant change.

The results from the application of the statistical tests to individual station data are summarised in Table 11. The number of stations indicating significant change varies from zero to 26. Again, if it is assumed that we need a significant result in at least three of the six tests applied to each data sequence to indicate change, then the number of stations indicating change for different months are given in Table 12.

The three winter months (June, July and August) show 15 to 19 stations with significant changes. Relatively, very few stations indicate change in summer and autumn months.

6. ANALYSIS OF RAINDAY DATA

6.1 Annual Rainday Data

The time series, moving average and Gaussian filter plots for the regional mean annual number of raindays are shown in Figs C1 to C8. All the regions, except region TAS, indicate a slight upward trend or jump in mean value during the latter part of the record. The region TAS shows an apparent downward trend since 1940 (Fig C8).

From the statistical analysis of the regional mean series, tests 1 to 4 indicate significant changes for all the regions (Table 13). Test 5 indicates significant changes for all the regions except region AN, while test 6 indicates significant changes for only two regions (AS and TAS). When tested individually, a large number of stations indicate significant changes (Table 14). If it is assumed, for this analysis, that we need a significant result in at least three tests to indicate change, then 41 stations indicate change (Table 15). Possible reasons for this large number showing changes are:

1. a likely change in the definition of a rainday with the introduction of the SI units; and,

2. the short length of rainday data compared to the rainfall data (hence only one flood dominated and one drought dominated period are covered by the records).

6.2 Monthly Rainday Data

The time series, moving average and Gaussian filter plots for the regional mean monthly raindays are shown in Figs C9 to C104.

For the region ST, an upward shift in mean value is only apparent in March (Fig C11) and September (Fig C17) since 1970. The remaining months do not indicate any apparent trend or change in mean level.

For the region SST, an apparent upward shift in the mean value is observed in January (Fig C21), August (Fig C28) and November (Fig C31) since 1970, in February (Fig C22) and October (Fig C30) since 1950 and in December (Fig C32) since 1960. The remaining months do not show any trend or change in mean value.

For the region U, an apparent upward shift is observed in January (Fig C33) and November (Fig C43) since 1970 and in February (Fig C34), May (Fig C37) and October (Fig C42) since 1950. The remaining months do not indicate any apparent trend or change in mean level.

For the region AS, an upward shift is apparent in February (Fig C46) since 1950 and in January (Fig C45), March (Fig C47), May (Fig C49), August (Fig C52), September (Fig C53), October (Fig C54) and November (Fig C55) since 1970. For the month July, high values are observed in the late 1950s and in the early 1960s. The remaining months do not indicate any apparent trend or change in mean level.

For the region AN, the number of raindays are mainly below average until 1940 and above average thereafter in January (Fig C57), February (Fig C58), April (Fig C60), May (Fig C61), October (Fig C66) and November (Fig C67). For the month September, an upward trend is apparent since 1940 (Fig C65). The remaining months do not indicate any apparent trend or change in mean level.

For the region WH, an upward shift is observed in April (Fig C72) since 1940, in June (Fig C74) and July (Fig C75) since 1960 and in August (Fig C76) since 1970. In February, an upward trend is apparent since 1950 (Fig C70) while in November (Fig C79) an upward shift is observed during the period 1940 to 1960. The remaining months do not indicate any apparent trend or change in mean level.

For the region WM, an upward shift is observed in January (Fig C81), March (Fig C84), August (Fig C88) and September (Fig C89) since 1970, in February (Fig C82) and April (Fig C84) since 1940 and in May (Fig C85), October (Fig C90) and November (Fig C91) since 1950. An upward trend is observed in December (Fig C92) since 1900. The remaining months do not indicate any apparent trend or change in mean level.

For the region TAS, a downward trend is observed in January (Fig C93) during 1940 to 1960 and in February (Fig C94) since 1960. A downward shift is observed in March (Fig C95) during 1950 to 1970 and in June (Fig C98), August (Fig C100) and October (Fig C102)

since 1960 and in July (Fig C99) since 1950. An upward shift is observed in April (Fig C96) during 1930 to 1940 and in November (Fig C103) during 1950 to 1960. The remaining months do not indicate any apparent trend or change in mean value.

The results from the application of statistical tests to the regional mean monthly rainday data are given in Table 16. Unlike rainfall data, most of the months and regions indicate change. This is again evident from the analysis of station rainday data (Table 17). Except for the month of June, all the other months have a large number of stations showing a trend (Table 18). The reasons for this are similar to those expressed for the annual data in Section 6.1.

7. ANALYSIS OF ANNUAL MAXIMUM DAILY RAINFALL DATA

The time series, moving average and Gaussian filter plots for the regional mean annual daily maximum rainfall are shown in Figs D1 to D8. For the region U (Fig D3), high values are observed in the 1890s, 1950s and 1920s and low values in the 1870s and in the 1940s. An upward shift is apparent since the 1950s. For the region AS, high values are observed at the beginning and end of the record (Fig D4), while most of the values in the period 1900 to 1950 are low. Low values are observed in the 1900s for the region AN (Fig D5). Very low values are observed at the beginning and end of the record for the region WH (Fig D6). For the region WM, a slight upward trend is apparent since about 1950 (Fig D7).

Application of the statistical tests to the regional mean maximum series indicate only 8 cases of significant change. Using the above criterion, of significant change in three tests as an indication of change, regions WM and AS show change. The change points are either late in the last century or early in the present century.

Results from the application of the statistical tests to individual station data are summarised in Tables 20 and 21. Only a small number of stations indicate change and using the above criterion, of at least three tests, only two stations indicate change. These are Busselton (09515) and Cape Otway Light House (90015). However, this number (two) could be obtained from a sample of 50 stations by chance alone.

8. CONCLUSIONS

Graphical plots of rainfall and rainday data indicate cyclic variations in the past. Statistical tests on annual rainfall and annual maximum daily rainfall data do not support the hypothesis that the climate has changed recently. A third of the stations indicate changes in the monthly rainfall in the winter months which implies, that the rainfall pattern within a year has changed for these stations. However, analyses carried out on rainday data indicate significant changes for all the regions with the change points before 1960, except for about nine

cases. Possible reasons for this might be a likely change in the definition of a rainday with the introduction of the SI units, and the shorter length of rainday data compared to the rainfall data. Hence, it can be concluded that there is no significant evidence of recent climate change within the analysed rainfall records.

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APPENDIX - A

TABLES

Table 1 List of rainfall stations used in the study.

Station number	Station name	Rainfall	Maximum	Rainday
02016	Kununurra	1896-1987	1907-1987	1907-1987
03006	Fitzroy Crossing	1894-1988		
03030	Broome (La Grange)	1891-1987	1907-1988	1907-1988
04035	Roebourne	1887-1988	1907-1988	1907-1988
05008	Mardie (Mardie)	1891-1987		1907-1988
05016	Onslow (Onslow P.O.)	1890-1987		
07017	Cue (Cue P.O.)	1895-1987	1907-1988	1907-1987
08025	Carnamah (Carnamah	1888-1987		
09034	Perth (Perth R.O.)	1876-1987	1880-1988	1880-1988
09500	Albany (Albany Town)	1877-1987		
09515	Busselton	1884-1988	1907-1988	
10058	Goomaling	1910-1988	1911-1988	
10144	York (York P.O.)	1877-1988		
10579	Katanning P.O.	1896-1988	1907-1988	1907-1988
12052	Menzies P.O.	1897-1987	1907-1988	1907-1987
14016	Darwin P.O.	1870-1988	1870-1988	1872-1988
14902	Catherine	1887-1988		1888-1984
15525	Barrow Creek	1874-1988	1884-1988	1884-1988
15557	Tempe Downs	1887-1988	1887-1988	1888-1988
16056	Yudnapinna	1885-1987	1885-1988	1885-1988
17031	Marree	1886-1988	1886-1988	1886-1988
18014	Cleve P.O.	1897-1987	1897-1985	1897-1985
23000	Adelaide (West Terrace)	1839-1979	1840-1978	1840-1978
24518	Meningie P.O.	1864-1988		
27005	Coen P.O.	1887-1988	1888-1988	1889-1988
28004	Parmerville	1890-1988	1890-1988	1890-1988
30018	Georgetown P.O.	1872-1988		1893-1988
31016	Cooktown P.O.	1878-1987	1904-1987	1904-1987
33007	Bowen P.O.	1871-1987	1888-1986	1889-1986
35019	Clermont P.O.	1871-1987	1888-1988	1888-1988
36143	Blackall P.O.	1880-1985	1887-1988	1887-1988
37043	Urandangie P.O.	1893-1988	1892-1988	1893-1988
38003	Boulia P.O.	1886-1988		1887-1988
39039	Gayndah P.O.	1871-1984		1906-1988

Table 1 (Cont.)

Station number	Station name	Rainfall	Maximum	Rainday
40214	Brisbane R.O.	1860-1988	1861-1968	1861-1988
43030	Roma P.O.	1894-1988	1894-1988	1894-1988
44026	Cunnamulla P.O.	1879-1987	1888-1988	1888-1988
46037	Tibooburra P.O.	1892-1988	1892-1988	1892-1988
48013	Bourke P.O.	1878-1987	1878-1988	1878-1988
49002	Balranald P.O.	1888-1987	1879-1988	
50014	Condobolin P.O.	1881-1988	1881-1988	
51010	Coonamble P.O.	1886-1988	1887-1988	1886-1988
54029	Warialda P.O.	1878-1988		1879-1975
56002	Armidale Radio Station	1878-1988	1872-1988	1872-1988
58012	Yamba Pilot Station	1878-1987	1878-1988	1882-1988
58063	Casino Airport	1879-1987	1880-1987	
61055	Newcastle	1867-1987	1867-1988	1867-1988
63004	Bathurst Gaol	1868-1983	1868-1982	1868-1988
64008	Coonabarabran P.O.	1880-1980	1880-1988	1880-1988
66062	Sydney R.O.	1859-1988	1859-1988	1859-1988
68045	Mossvale P.O.	1870-1988		
70025	Crookwell P.O.	1884-1987		
73056	Young P.O.	1872-1988	1872-1986	
74009	Berrigan P.O.	1875-1988		
75031	Hay P.O.	1881-1988		
77042	Swan Hill P.O.	1885-1987	1885-1988	1885-1988
79023	Horsham	1874-1988		
81003	Bendigo Prison	1862-1987	1881-1988	1881-1988
83025	Omeo	1880-1988	1880-1988	1880-1988
86071	Melbourne R.O.	1856-1987	1856-1988	1856-1988
87021	Durdiwarrah	1874-1985	1893-1988	1893-1988
88001	Alexandra P.O.	1879-1988		
88043	Maryborough	1878-1988	1878-1988	1878-1988
90015	Cape Otway Light House	1864-1988	1872-1988	1872-1988
91057	Low Head Light House	1883-1988	1901-1988	1901-1988
92038	Swansea P.O.	1885-1988		
93014	Oatlands P.O.	1898-1988	1907-1988	1907-1988
94010	Cape Bruny Ligh House	1871-1988	1907-1988	1907-1988
95003	Bushy Park	1874-1987	1908-1988	1908-1988

Table 2 Basic parameters of annual rainfall.

Station Number	Station Name	Length (years)	Mean (mm)	C_v	C_s	r_1
02016	Kununurra	92	603	0.270	0.095	0.054
03006	Fitzroy Crossing	95	533	0.319	0.062	0.104
03030	Broome (La Grange Mission)	97	484	0.454	0.516	0.170
04035	Roebourne (Roebourne P.O.)	102	311	0.577	1.063	-0.076
05008	Mardie (Mardie)	97	263	0.601	0.819	-0.064
05016	Onslow (Onslow P.O.)	98	270	0.715	1.195	-0.160
07017	Cue (Cue P.O.)	93	224	0.455	0.857	-0.123
08025	Carnamah (Carnamah P.O.)	100	390	0.270	0.508	0.033
09034	Perth (Perth R.O.)	112	869	0.189	0.093	-0.050
09500	Albany (Albany Town)	111	932	0.166	0.228	0.097
09515	Busselton (Busselton P.O.)	105	828	0.172	0.348	-0.004
10058	Goomaling (Goomaling Composit	79	367	0.253	0.277	-0.152
10144	York (York P.O.)	112	452	0.235	0.348	-0.149
10579	Katanning P.O.	93	487	0.201	0.230	-0.143
12052	Menzies P.O.	91	241	0.432	0.918	-0.041
14016	Darwin P.O.	119	1592	0.196	0.400	-0.003
14902	Catherine (Catherine Depot)	102	967	0.256	0.114	0.079
15525	Barrow Creek	115	312	0.537	1.652	0.278
15557	Tempe Downs	102	256	0.572	1.698	0.299
16056	Yudnapinna	103	209	0.432	1.313	0.213
17031	Marree	103	161	0.491	1.268	0.121
18014	Cleve P.O.	91	398	0.231	-0.055	-0.097
23000	Adelaide (West Terrace)	141	530	0.204	0.043	-0.008
24518	Meningie P.O.	125	470	0.208	0.100	0.100
27005	Coen P.O.	102	1163	0.276	0.313	0.059
28004	Parmerville	99	1038	0.295	0.698	0.041
30018	Georgetown P.O.	117	829	0.351	0.881	0.241
31016	Cooktown P.O.	110	1804	0.287	0.534	-0.005
33007	Bowen P.O.	116	1012	0.405	0.326	0.164
35019	Clermont P.O.	117	671	0.375	0.435	0.087
36143	Blackall P.O.	106	526	0.418	1.169	0.172
37043	Urandangie P.O.	96	293	0.539	1.085	0.090
38003	Boulia P.O.	103	263	0.616	1.297	0.160
39039	Gayndah P.O.	114	778	0.273	0.382	-0.041
40214	Brisbane R.O.	129	1156	0.311	0.607	0.018

Table 2 (Cont.)

Station Number	Station Name	Length (years)	Mean (mm)	C_v	C_s	r_1
43030	Roma P.O.	95	579	0.307	0.352	0.080
44026	Cunnamulla P.O.	109	365	0.428	0.912	0.128
46037	Tibooburra P.O.	97	223	0.589	1.448	0.124
48013	Bourke P.O.	110	349	0.432	0.735	0.072
49002	Balranald P.O.	100	320	0.358	0.736	0.158
50014	Condobolin P.O.	108	443	0.329	0.701	0.022
51010	Coonamble P.O.	103	499	0.331	0.645	0.120
54029	Warialda P.O.	111	685	0.267	0.288	0.028
56002	Armidale Radio Station	111	777	0.224	0.629	0.203
58012	Yamba Pilot Station	110	1461	0.251	0.645	0.006
58063	Casino Airport	109	1110	0.254	0.382	0.059
61055	Newcastle (Nobbys Signal Stat	121	1134	0.252	0.616	0.202
63004	Bathurst Gaol	116	626	0.279	0.524	0.029
64008	Coonabarabran P.O.	109	734	0.309	0.765	0.083
66062	Sydney R.O.	130	1218	0.271	0.603	0.075
68045	Mossvale P.O.	119	993	0.269	0.452	0.114
70025	Crookwell P.O.	104	865	0.243	0.061	-0.019
73056	Young P.O.	117	652	0.297	0.347	0.080
74009	Berrigan P.O.	114	448	0.327	0.798	0.011
75031	Hay P.O.	108	364	0.349	1.230	0.152
77042	Swan Hill P.O.	103	346	0.316	0.627	0.066
79023	Horsham	115	450	0.228	0.141	0.073
81003	Bendigo Prison	126	550	0.266	0.195	-0.010
83025	Omeo	109	676	0.208	0.297	0.021
86071	Melbourne R.O.	132	655	0.194	0.052	0.023
87021	Durdiwarrah	112	687	0.220	0.724	-0.020
88001	Alexandra P.O.	110	711	0.205	0.326	-0.043
88043	Maryborough	111	531	0.243	0.156	0.051
90015	Cape Otway Light House	125	889	0.149	0.447	0.056
91057	Low Head Light House	106	681	0.210	0.427	0.058
92038	Swansea P.O.	104	609	0.281	0.893	0.141
93014	Oatlands P.O.	91	561	0.228	0.533	0.097
94010	Cape Bruny Ligh House	118	947	0.162	0.164	0.250
95003	Bushy Park (Hops reach)	114	582	0.179	0.224	0.065

Table 3 Basic parameters of annual number of raindays.

Station Number	Station Name	Length (years)	Mean (mm)	C_v	C_s	r_1
02016	Kununura	81	42	0.258	0.365	0.299
03030	Broome (La Grange)	82	31	0.308	0.013	0.118
04035	Roebourne	82	23	0.370	0.329	0.073
05008	Mardie	82	22	0.395	0.431	0.249
07017	Cue	81	42	0.267	0.436	-0.057
09034	Perth	109	119	0.118	0.213	0.101
10579	Katanning P.O.	82	116	0.132	0.060	0.152
12052	Menzies P.O.	81	47	0.259	0.095	0.077
14016	Darwin P.O.	117	102	0.133	0.177	0.239
14902	Catherine	97	65	0.195	0.330	0.355
15525	Barrow Creek	105	33	0.327	0.811	0.335
15557	Tempe Downs	101	26	0.468	0.877	0.436
16056	Yudnapinna	104	41	0.419	0.489	0.504
17031	Marree	103	28	0.346	0.842	0.352
18014	Cleve P.O.	89	102	0.192	-0.133	0.519
23000	Adelaide West Terrace	139	121	0.119	-0.121	0.073
27005	Coen P.O.	100	85	0.213	0.222	0.185
28004	Parmerville	99	82	0.187	0.136	0.049
30018	Georgetown P.O.	96	58	0.245	0.517	0.155
31016	Cooktown P.O.	84	130	0.187	0.162	0.356
33007	Bowen P.O.	98	74	0.238	0.338	0.242
35019	Clermont P.O.	101	56	0.254	0.084	0.178
36143	Blackall P.O.	102	50	0.268	0.551	0.055
37043	Urandangie P.O.	96	29	0.386	0.836	0.345
38003	Boulia P.O.	102	29	0.400	0.685	0.244
39039	Gayndah P.O.	83	73	0.178	-0.074	0.222
40214	Brisbane R.O.	128	122	0.165	0.170	0.072
43030	Roma P.O.	95	56	0.227	-0.006	0.062
44026	Cunnamulla P.O.	101	42	0.332	1.003	0.211
46037	Tibooburra P.O.	97	29	0.399	0.806	0.253
48013	Bourke P.O.	109	46	0.281	0.373	0.052
51010	Coonamble P.O.	103	60	0.252	0.311	0.208
54029	Warialda P.O.	97	71	0.235	0.562	0.366
56002	Armidale Radio Station	117	109	0.187	0.184	0.370
58012	Yamba Pilot Station	107	133	0.166	0.095	0.251
61055	Newcastle	122	133	0.165	0.643	0.471
63004	Bathurst Gaol	115	88	0.210	0.415	0.251
64008	Coonabarabran P.O.	109	78	0.221	0.481	0.240
66062	Sydney R.O.	130	138	0.133	0.292	0.135
77042	Swan Hill P.O.	104	69	0.228	0.507	0.188
81003	Bendigo Prison	108	102	0.161	-0.158	-0.061
83025	Omeo	109	122	0.182	0.388	0.414
86071	Melbourne R.O.	133	147	0.106	0.065	0.194
87021	Urdidwarrah	96	166	0.125	-0.040	0.415
88043	Maryborough	111	104	0.221	0.239	0.525
90015	Cape Ottway	117	178	0.124	0.102	0.634
91057	Low Head Light House	88	143	0.145	0.846	0.407
93014	Oatlands PO	82	160	0.183	0.427	0.539
94010	Cape Bruny Light House	82	213	0.105	-0.186	0.498
95003	Bushy Park	81	147	0.135	0.490	0.215

Table 4 Basic parameters of annual maximum daily rainfall.

Station Number	Station Name	Length (years)	Mean (mm)	C_v	C_s	r_1
02016	Kununurra	81	71	0.363	1.021	-0.035
03030	Broome (La Grange Mission)	82	101	0.733	2.679	-0.029
04035	Roebourne P.O.	82	85	0.659	0.898	-0.042
07017	Cue P.O.	82	38	0.591	1.545	-0.025
09034	Perth R.O.	109	51	0.270	0.961	0.183
09515	Busselton P.O.	82	50	0.443	0.526	0.209
10058	Goomaling	78	34	0.438	1.922	-0.030
10579	Katanning	82	40	0.488	2.312	-0.211
12052	Menzies P.O.	82	36	0.632	1.816	-0.118
14016	Darwin P.O	119	121	0.360	1.453	-0.025
15525	Barrow Creek	105	58	0.617	1.877	0.124
15557	Tempe Downs	102	47	0.526	1.397	0.072
16016	Yudnapinna	104	33	0.579	2.101	0.064
17031	Marree	103	36	0.727	2.817	-0.075
18014	Cleve P.O.	89	36	0.457	2.381	-0.049
23000	Adelaide West Terrace	139	37	0.440	2.411	-0.174
27005	Coen P.O.	101	115	0.518	2.036	0.026
28004	Parmerville	99	94	0.391	2.038	0.005
31016	Cooktown P.O.	84	164	0.478	1.341	-0.107
33007	Bowen P.O.	99	142	0.500	0.998	0.134
35019	Clermont P.O.	101	82	0.552	4.275	-0.021
36143	Blackall P.O.	102	73	0.406	0.785	0.156
37043	Urandangie P.O.	97	58	0.568	1.277	-0.011
41214	Brisbane R.O.	128	108	0.575	2.240	0.016
43030	Roma P.O.	95	65	0.396	1.622	-0.043
44026	Cunnamulla P.O.	101	54	0.491	1.105	0.068
46037	Tibooburra	97	45	0.603	1.845	-0.053
48013	Bourke P.O.	110	50	0.455	1.070	0.073
49002	Balranald P.O.	110	37	0.424	0.782	0.020
50014	Condobolin P.O.	108	46	0.475	1.205	0.038
51010	Coonamble P.O.	102	56	0.383	0.932	0.098
56002	Armidale Radio Station 2UD	117	58	0.374	1.354	0.025
58012	Yamba Pilot Station	111	113	0.407	1.462	-0.056
58063	Casino Airport	108	93	0.511	1.581	-0.012
61005	Newcastle	122	90	0.496	2.202	0.132
63004	Bathurst Gaol	115	49	0.369	1.305	0.106
64008	Coonabaran P.O.	109	71	0.387	1.565	-0.028
66062	Sydney R.O.	130	112	0.425	1.417	-0.079
73056	Young P.O.	115	53	0.415	0.904	-0.096
77042	Swan Hill P.O.	104	35	0.377	0.711	-0.158
81003	Bendigo Prison	108	44	0.360	0.511	0.132
83025	Omeo	109	47	0.360	1.379	-0.092
86071	Melbourne R.O.	133	47	0.366	0.948	-0.018
87021	Durdiwarrah	96	52	0.438	1.012	-0.046
88043	Maryborough	111	41	0.362	1.036	0.046
90015	Cape Ottway Light House	117	41	0.367	1.528	0.177
91057	Low Head Light House	88	38	0.404	2.241	0.040
93014	Oatlands P.O.	82	42	0.427	1.101	-0.101
94010	Cape Bruny Light House	82	42	0.453	2.043	-0.098
95003	Bushy Park	81	31	0.342	1.464	-0.061

Table 5 Number of rainfall stations in each climatic region.

Region		Number of stations		
		Rainfall	Daily maximum	Rainday
Summer Rainfall Tropical	(ST)	11	8	10
Summer Rainfall Subtropical	(SST)	8	6	7
Uniform Rainfall Temperate	(U)	13	10	8
Summer Rainfall Arid	(AS)	10	7	9
Non-Seasonal/Winter Rainfall Arid	(AN)	4	4	4
Winter Rainfall (moderate to heavy) Temperate	(WH)	7	5	2
Winter Rainfall (mainly moderate) Temperate	(WM)	11	6	6
Winter Rainfall (Tasmania) Temperate	(TAS)	5	4	4

Table 6 Results of the statistical tests for regional mean annual rainfall.

Region	Test					
	1	2	3	4	5	6
ST	NS	NS	NS	NS	NS	S(1935)
SST	NS	NS	NS	NS	NS	NS
U	NS	NS	NS	NS	NS	NS
AS	NS	NS	NS	NS	NS	S(1901)
AN	NS	NS	NS	NS	NS	NS
WH	NS	NS	NS	NS	NS	S(1917)
WM	NS	NS	NS	NS	NS	NS
TAS	NS	NS	NS	NS	NS	NS

Values in parentheses indicate change points.

Table 7 Number of stations indicating significant trend or change in mean value at 5% level for annual rainfall.

Test	Number of stations
Mann-Kendall	3
Spearman	3
Cumulative sums	12
Likelihood ratio	10
Distribution-free CUSUM	2
Two-phase regression	11

Table 8 Number of stations indicating significant trend or change in mean value for a given number of tests for annual rainfall.

Number of tests indicating change	Number of stations
0	47
1	10
2	6
3	4
4	2
5	0
6	0

Table 9 Annual mean during flood dominated and drought dominated periods.

Station number	Station name	Mean (mm) F1	D1	F2	Station number	Station name	Mean (mm) F1	D1	F2
02016	Kununurra	610	605	602	43030	Roma P.O.	513	541	630
03006	Fitzroy Xing	628	520	528	44026	Cunnamulla P.O.	396	326	385
03030	La Grange	548	465	503	46037	Tibooburra P.O.	203	195	254
04035	Roebourne	370	298	313	48013	Bourke P.O.	418	301	367
05008	Mardie	204	254	299	49002	Balranald P.O.	324	283	369
05016	Onslow P.O.	192	256	308	50014	Condobolin P.O.	472	400	486
07017	Cue P.O.	218	227	229	51010	Coonamble P.O.	546	440	545
08025	Carnamah	364	414	371	54029	Warialda P.O.	740	642	710
09034	Perth R.O.	845	916	832	56002	Armidale R.S.	805	744	789
09500	Albany Town	867	1004	891	58012	Yamba P.S.	1513	1354	1572
09515	Busselton	757	868	808	58063	Casino Airport	1183	1040	1149
10058	Goomaling		366	369	61055	Newcastle	1251	1033	1146
10144	York P.O.	443	461	455	63004	Bathurst Gaol	639	569	698
10579	Katanning P.O.	442	497	486	64008	Coonabarabran	780	651	816
12052	Menzies P.O.	181	245	247	66062	Sydney R.O.	1252	1089	1312
14015	Darwin P.O.	1590	1501	1699	68045	Mossvale P.O.	1031	923	1034
14902	Catherine	1039	920	995	70025	Crookwell P.O.	838	845	912
15525	Barrow Creek	316	298	330	73056	Young P.O.	668	602	692
15557	Tempe Downs	240	230	296	74009	Berrigan P.O.	471	414	469
16056	Yudnapinna	194	203	227	75031	Hay P.O.	369	334	401
17031	Marree	144	152	179	77042	Swan Hill P.O.	347	320	379
18014	Cleve P.O.	286	395	413	79023	Horsham	433	455	457
23000	Adelaide	514	543	508	81003	Bendigo Prison	544	517	592
24518	Meningie P.O.	473	454	485	83025	Omeo	665	653	708
27005	Coen P.O.	1084	1136	1211	86071	Melbourne R.O.	638	649	664
28004	Parmerville	1024	1035	1038	87021	Durdiwarrah	667	652	744
30018	Georgetown	920	732	875	88001	Alexandra P.O.	698	691	744
31016	Cooktown P.O.	1796	1704	1948	88043	Maryborough	511	506	573
33007	Bowen P.O.	1055	961	1036	90015	Cape Otway L.H.	862	866	945
35019	Clermont P.O.	737	627	683	91057	Low Head L.H.	672	690	680
36143	Blackall P.O.	565	500	543	92038	Swansea P.O.	694	590	597
37043	Urandangie P.O.	300	265	323	93014	Oatlands P.O.	436	572	557
38003	Boulia P.O.	288	245	274	94010	Cape Bruny L.H.	978	895	992
39039	Gayndah P.O.	802	752	799	95003	Bushy Park	579	575	597
40214	Brisbane R.O.	1283	1017	1185					

F1 - Flood dominated regime 1864-1900
D1 - Drought dominated regime 1901-1948
F2 - Flood dominated regime 1949 onwards

Table 10 Results of the statistical analysis of regional mean monthly rainfall time series.

Month	Region	Test					
		1	2	3	4	5	6
January	WM	S	S			S(1932)	
	AS				S(1878)		S(1882)
February	AN	S	S	S(1937)			
March	AN						S(1921)
April	SST				S(1987)		
	AS				S(1891)		
May	ST						S(1898)
June	SST					S(1924)	
July	AN	S	S				
August	ST				S(1870)		S(1873)
	SST				S(1863)		S(1862)
	AS					S(1951)	
	AN				S(1887)		
	WH				S(1864)		
September	U				S(1859)		S(1861)
	AS				S(1880)		
October							
November	WM				S(1839)		
	TAS			S(1890)	S(1885)		S(1896)
December	AN						S(1889)

Values in parentheses indicate change points.

Table 11 Number of stations indicating significant trend or change in mean value for monthly station rainfall at 5% level.

Month	Test						7
	1	2	3	4	5	6	
January	14	11	9	8	5	2	
February	4	4	4	6	1	6	
March	4	0	0	4	0	4	
April	13	4	1	10	2	6	
May	13	7	3	8	4	9	
June	21	26	17	14	20	1	
July	22	22	8	11	12	5	
August	21	24	9	15	19	12	
September	16	10	3	6	9	6	
October	9	9	8	12	8	4	
November	7	7	4	10	6	8	
December	3	7	1	8	2	7	

Table 12 Number of stations indicating significant trend or change in mean monthly rainfall in a given number of tests.

Month	Number of tests indicating change						
	1	2	3	4	5	6	>2
January	6	4	5	3	2	0	10
February	10	5	0	1	0	0	1
March	5	3	0	0	0	0	0
April	13	10	0	0	0	0	0
May	10	10	4	0	0	0	4
June	7	5	6	3	9	1	19
July	4	10	8	5	1	1	15
August	10	8	10	4	5	0	19
September	9	7	8	2	0	0	10
October	8	9	6	1	0	0	7
November	11	3	5	2	0	0	7
December	3	6	2	0	0	0	2

Table 13 Results of the statistical tests for regional mean annual number of raindays.

Region	Test					
	1	2	3	4	5	6
ST	S	S	S(1953)	S(1884)	S(1953)	NS
SST	S	S	S(1948)	S(1948)	S(1946)	NS
U	S	S	S(1929)	S(1946)	S(1929)	NS
AS	S	S	S(1946)	S(1972)	S(1946)	S(1937)
AN	S	S	S(1940)	S(1940)	NS	NS
WH	S	S	S(1914)	S(1914)	S(1931)	NS
WM	S	S	S(1930)	S(1930)	S(1930)	NS
TAS	S	S	S(1957)	S(1958)	S(1958)	S(1928)

Values in parentheses indicate change points.

Table 14 Number of stations indicating significant trend or change in mean value at 5% level for annual number of raindays.

Test	Number of stations
Mann-Kendall	33
Spearman	36
Cumulative sums	42
Likelihood ratio	42
Distribution-free CUSUM	24
Two-phase regression	26

Table 15 Number of stations indicating change as a function of the number of tests for annual number of raindays.

Number of tests indicating change	Number of stations
0	5
1	2
2	2
3	2
4	15
5	14
6	10

Table 16 Results of the statistical analysis of regional mean monthly rainday time series.

Month	Region	Test					
		1	2	3	4	5	6
January	AS	S	S	S(1953)	S(1973)		
	AN	S	S	S(1936)	S(1936)	S(1936)	
	WH	S	S	S(1915)	S(1915)	S(1912)	S(1884)
	WM	S	S	S(1933)	S(1970)	S(1927)	
	TAS		S	S(1951)		S(1950)	
February	SST		S	S(1941)			
	AS						S(1902)
	AN	S	S	S(1941)	S(1941)		S(1978)
	WH	S	S				
	WM	S	S	S(1923)	S(1923)	S(1916)	S(1972)
	TAS			S(1964)	S(1964)		
March	U	S	S				
	WM		S		S(1967)		
	TAS			S(1948)			
April	WH	S	S	S(1930)	S(1925)	S(1930)	
	WM	S	S	S(1930)	S(1931)		
	TAS					S(1944)	
May	ST					S(1954)	S(1927)
	AS						S(1901)
	WH		S				
	WM	S	S	S(1941)			
June	U						S(1890)
	WH	S	S	S(1914)			
	TAS	S	S	S(1956)	S(1956)	S(1943)	
July	ST						S(1888)
	AS		S				
	AN	S	S	S(1940)	S(1940)	S(1937)	
	WH	S	S	S(1925)	S(1908)		
	WM	S	S	S(1929)	S(1939)	S(1929)	
	TAS			S(1948)			S(1970)
August	ST	S	S		S(1885)		
	SST	S	S				
	U	S	S	S(1928)		S(1949)	
	AS	S	S	S(1950)	S(1964)		
	WM	S	S				
	TAS				S(1904)		S(1906)

Values in parentheses indicate change points.

Table 16 (Cont.)

Month	Region	Test					
		1	2	3	4	5	6
September	U				S(1860)		
	AS				S(1879)		S(1881)
	AN			S(1944)	S(1954)		
	WM	S	S				
	TAS	S	S	S(1948)	S(1948)		
October	SST	S	S	S(1948)	S(1948)	S(1946)	
	U		S	S(1946)	S(1946)		
	AS	S	S	S(1946)			
	AN	S	S	S(1946)	S(1972)		
	WH				S(1887)		S(1889)
	WM	S	S	S(1914)	S(1914)	S(1914)	
	TAS		S	S(1958)		S(1952)	
November	ST	S	S	S(1884)	S(1881)	S(1946)	S(1886)
	SST	S	S	S(1923)	S(1958)	S(1930)	
	U	S	S	S(1928)	S(1968)	S(1928)	
	AN	S	S	S(1945)	S(1945)	S(1943)	
	WH	S	S	S(1938)	S(1938)	S(1938)	
	WM	S	S	S(1938)	S(1943)	S(1943)	
December	SST	S	S	S(1954)	S(1957)		
	U	S	S	S(1913)			
	AN	S	S		S(1987)		
	WM	S	S	S(1931)	S(1931)		

Values in parentheses indicate change points.

Table 17 Number of stations indicating significant trend or change in mean value for monthly station raindays at 5% level.

Month	Test					
	1	2	3	4	5	6
January	28	22	13	16	26	0
February	31	19	17	13	27	9
March	27	15	13	13	26	3
April	33	9	10	11	26	9
May	36	20	15	14	25	8
June	20	13	6	6	32	4
July	34	22	10	12	30	7
August	36	29	15	16	33	8
September	39	22	11	16	31	6
October	39	26	26	19	35	6
November	42	25	16	22	32	8
December	30	20	13	13	24	3

Table 18 Number of stations indicating change as a function of the number of tests for monthly number of raindays.

Month	Number of tests indicating change						
	1	2	3	4	5	6	>2
January	13	7	7	9	3	0	19
February	18	12	3	6	5	2	16
March	20	9	2	8	5	0	15
April	15	16	7	2	3	1	13
May	6	12	10	7	6	0	23
June	23	11	5	1	3	0	9
July	11	13	8	4	6	1	19
August	12	6	6	11	6	3	26
September	17	6	10	7	5	2	24
October	10	7	11	11	8	1	31
November	8	15	5	9	10	1	25
December	11	10	5	8	5	0	18

Table 19 Results of the statistical tests for regional mean annual maximum daily rainfall.

Region	Test					
	1	2	3	4	5	6
ST	NS	NS	NS	NS	NS	NS
SST	NS	NS	NS	NS	NS	NS
U	NS	NS	NS	NS	NS	S(1858)
AS	NS	NS	S(1898)	S(1882)	NS	S(1906)
AN	NS	S	NS	NS	NS	NS
WH	NS	NS	NS	NS	NS	NS
WM	S	S	NS	NS	S(1909)	NS
TAS	NS	NS	NS	NS	NS	NS

Values in parentheses indicate change points.

Table 20 Number of stations indicating significant trend or change in mean value at 5% level for annual maximum daily rainfall.

Test	Number of stations
Mann-Kendall	3
Spearman	5
Cumulative sums	2
Likelihood ratio	8
Distribution-free CUSUM	1
Two-phase regression	5

Table 21 Number of stations indicating change as a function of the number of tests for annual maximum daily rainfall.

Number of tests indicating change	Number of stations
0	38
1	9
2	1
3	0
4	1
5	1
6	0

APPENDIX - B

FIGURES FOR THE ANALYSIS OF RAINFALL DATA

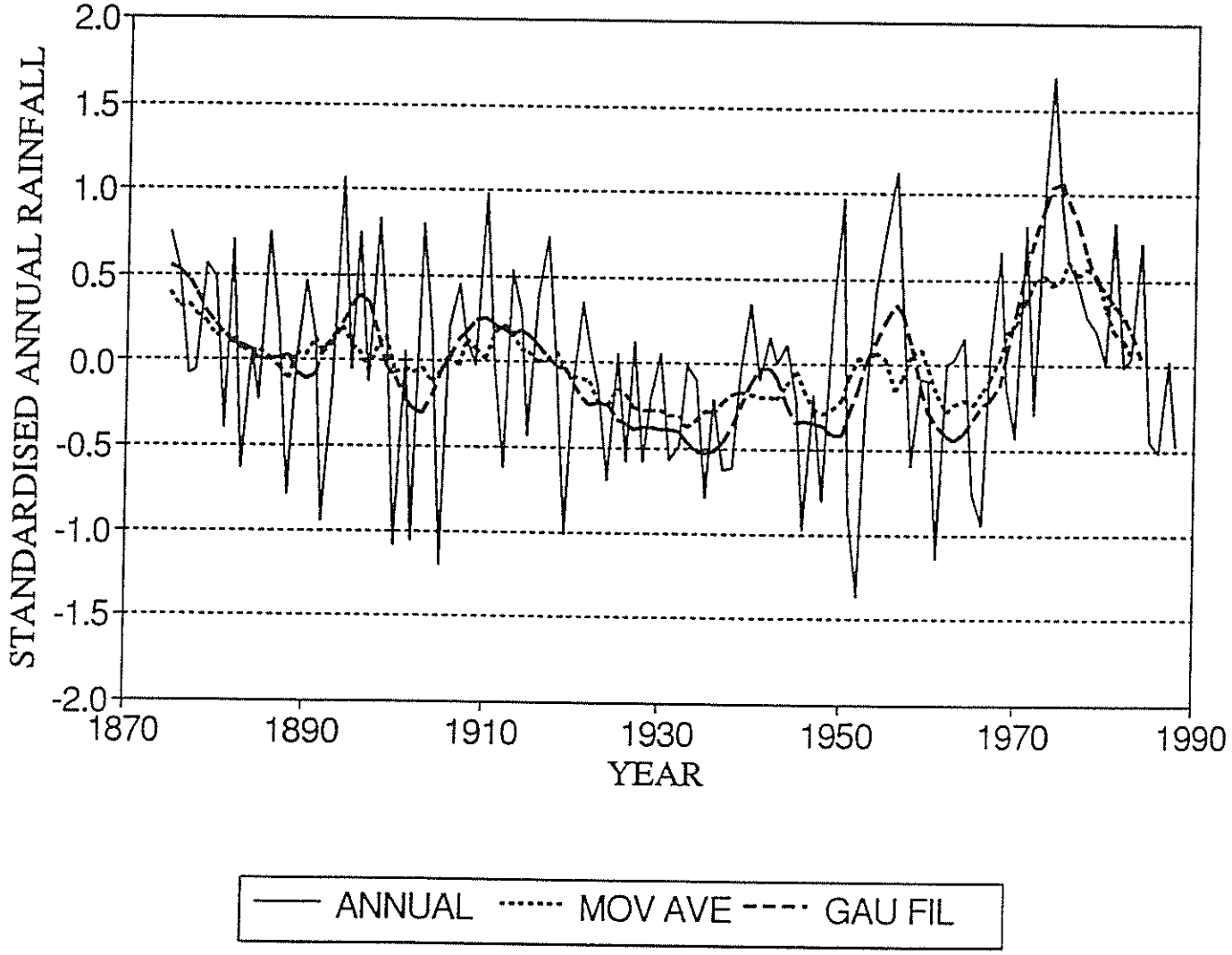


Fig B1. Plot of annual rainfall time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - tropical region.

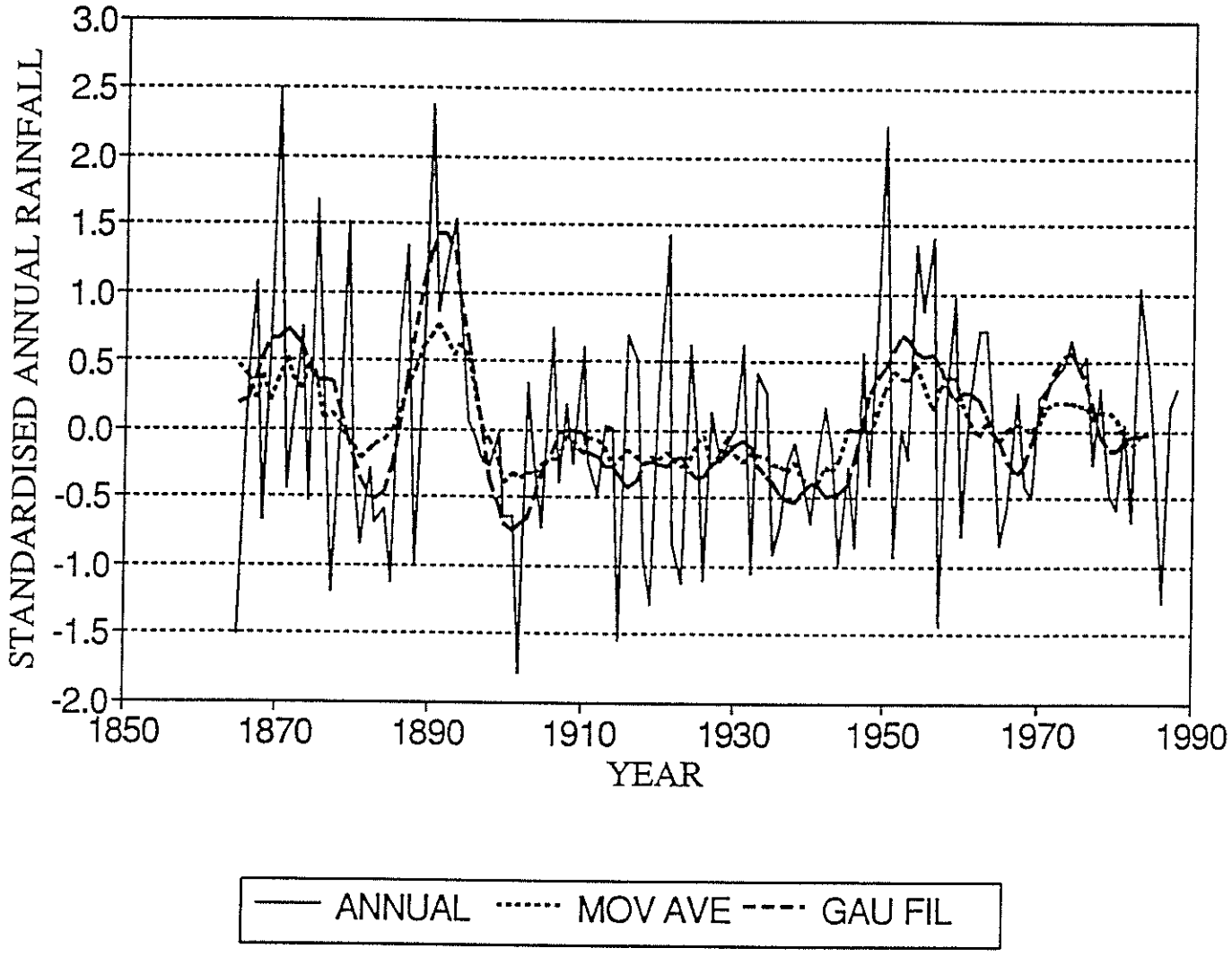


Fig B2. Plot of annual rainfall time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - subtropical region.

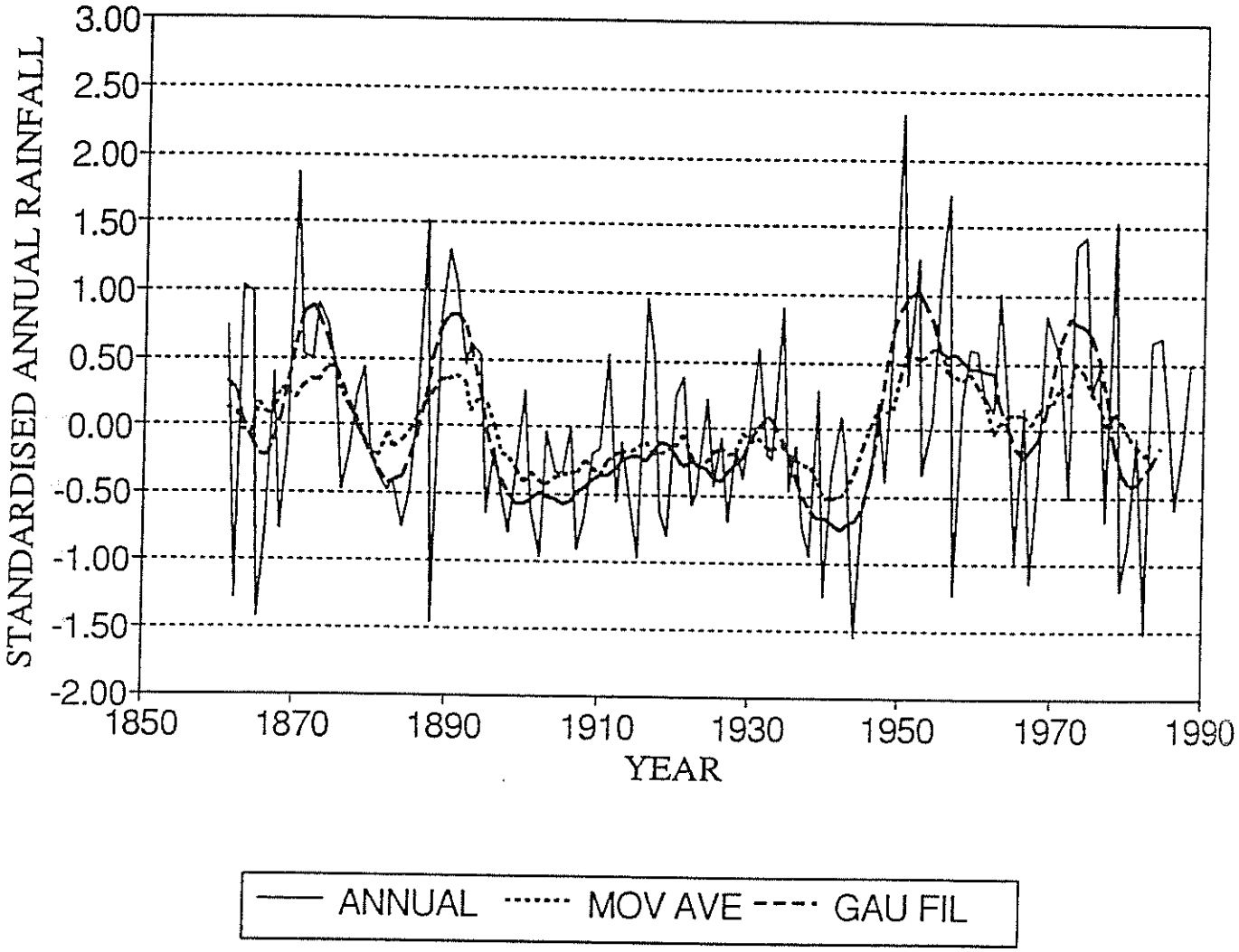


Fig B3 Plot of annual rainfall time series with 11 year moving average and 11 point Gaussian filter for uniform rainfall - temperate region.

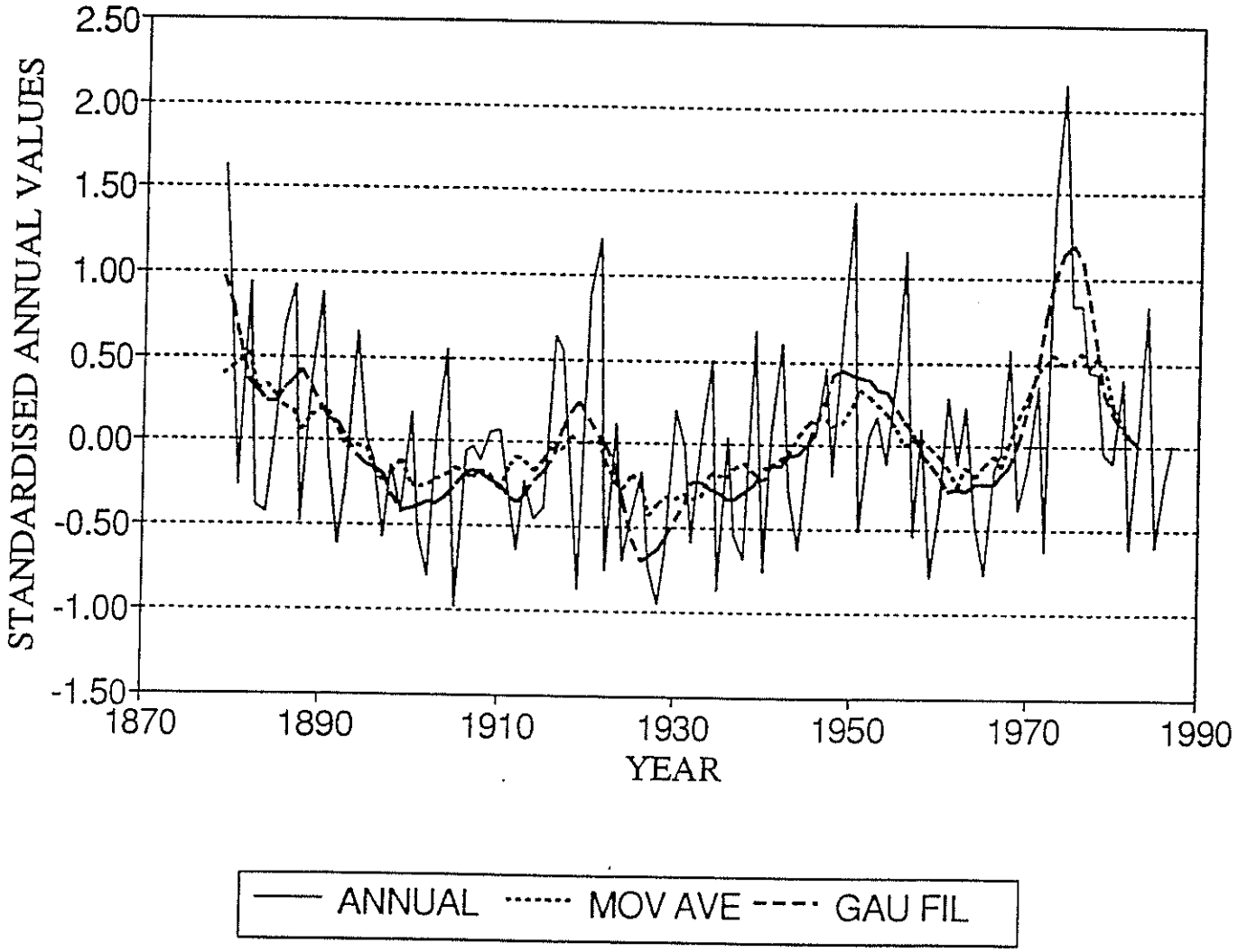


Fig B4 Plot of annual rainfall time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - arid region.

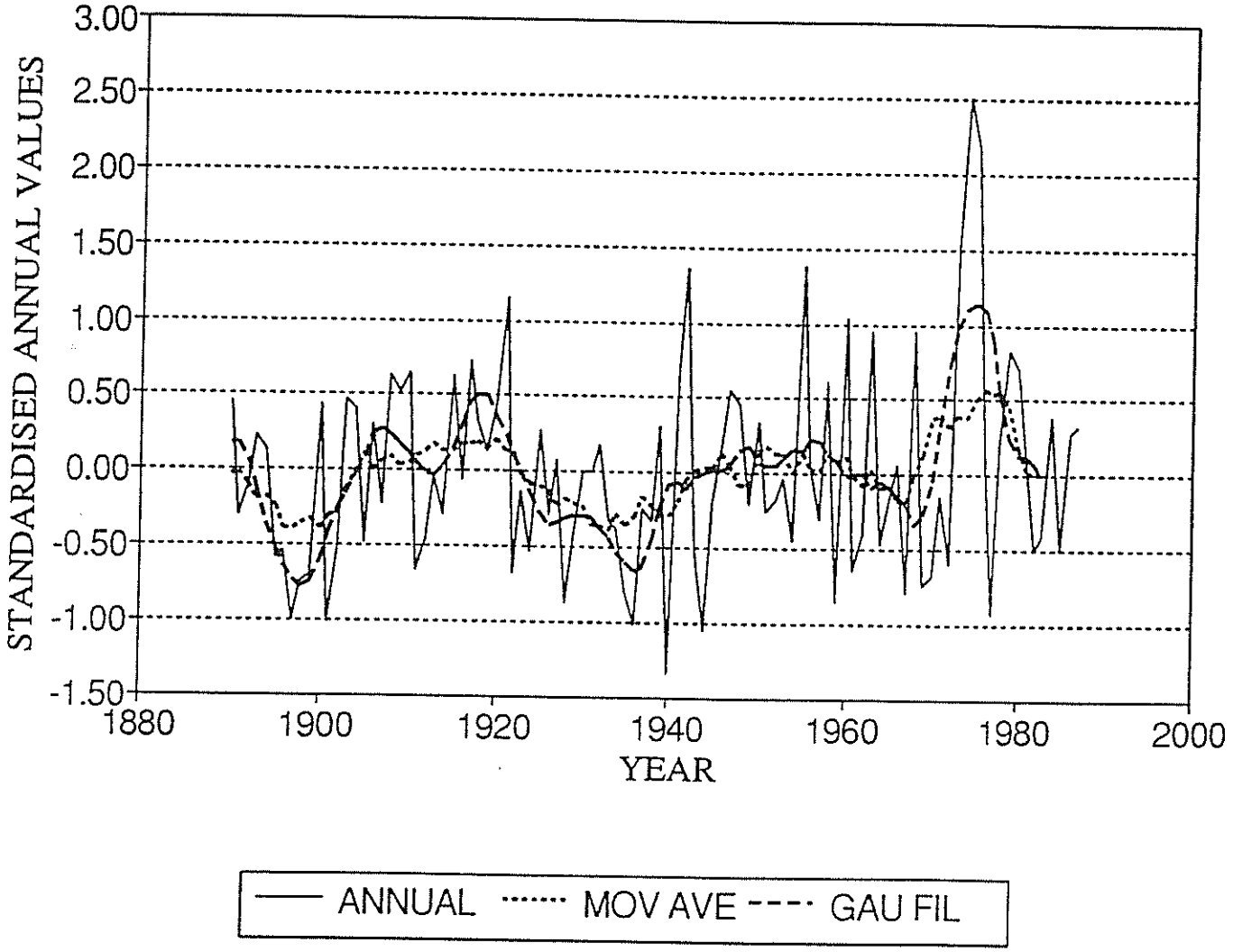


Fig B5 Plot of annual rainfall time series with 11 year moving average and 11 point Gaussian filter for winter/non-seasonal rainfall - arid region.

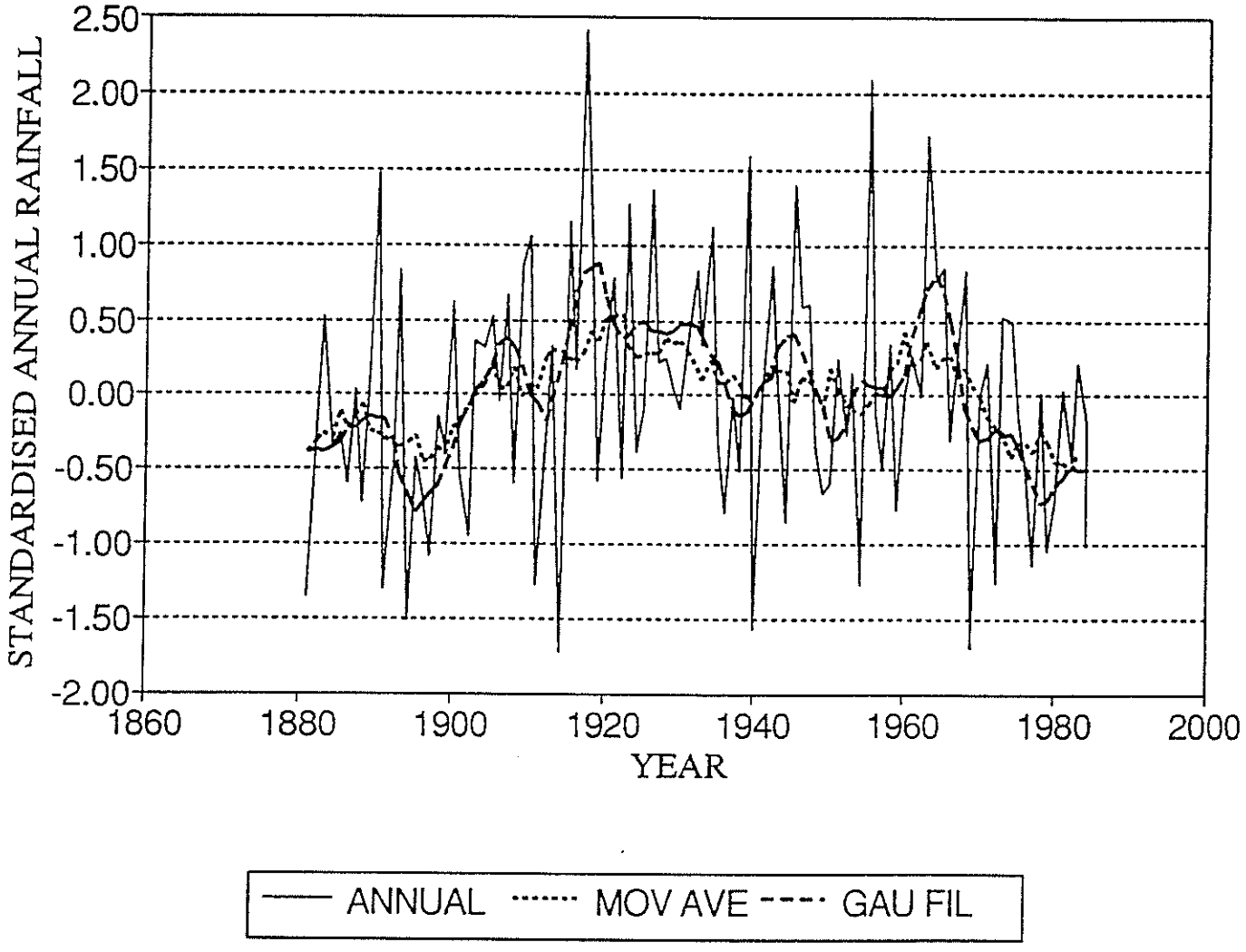


Fig B6 Plot of annual rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (Moderate to heavy rainfall) - temperate region.

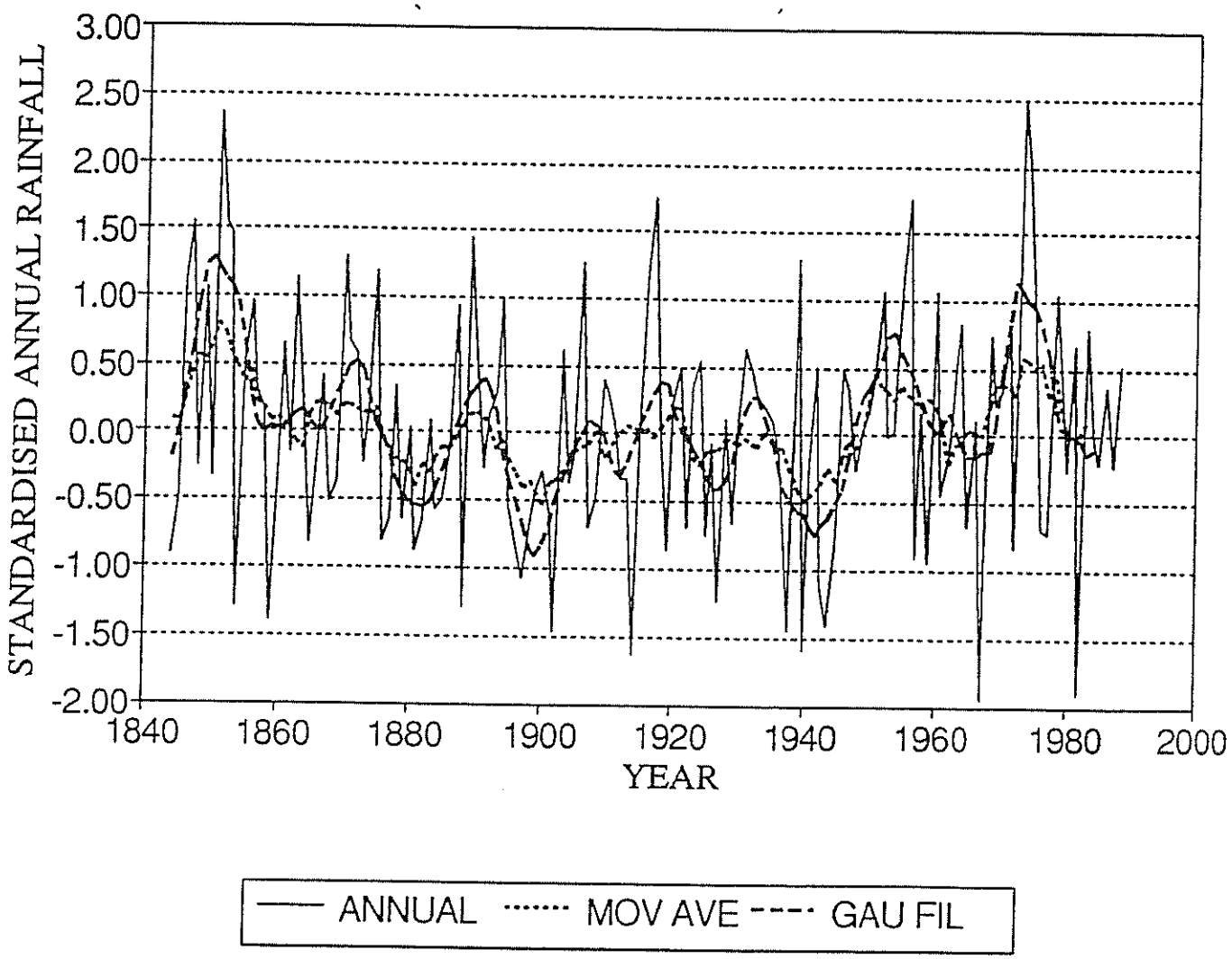


Fig B7 Plot of annual rainfall time series with 11 year moving average and 11 point Gaussian filter for (mainly moderate rainfall) - temperate region.

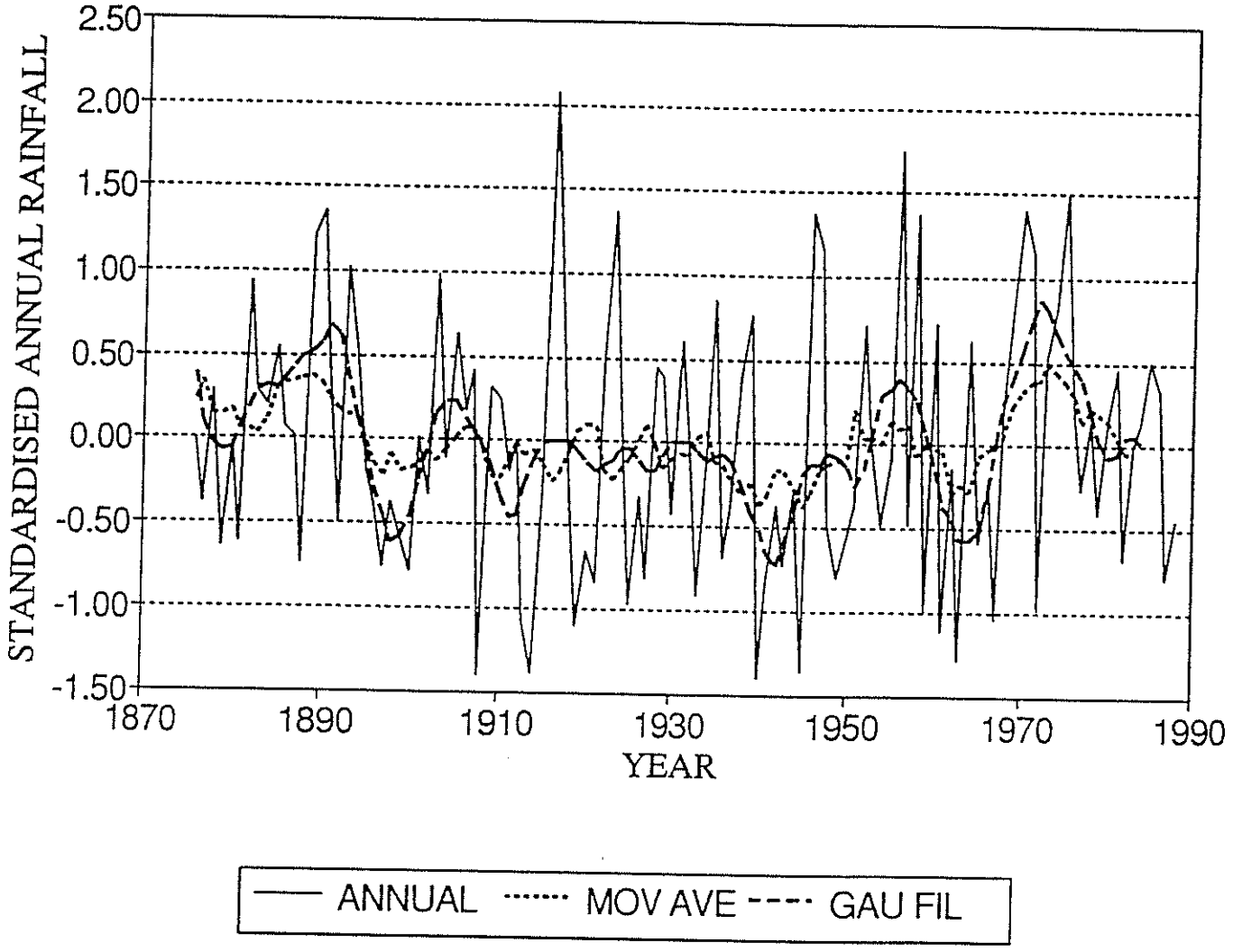


Fig B8 Plot of annual rainfall time series with 11 year moving average and 11 point Gaussian filter for Tasmania.

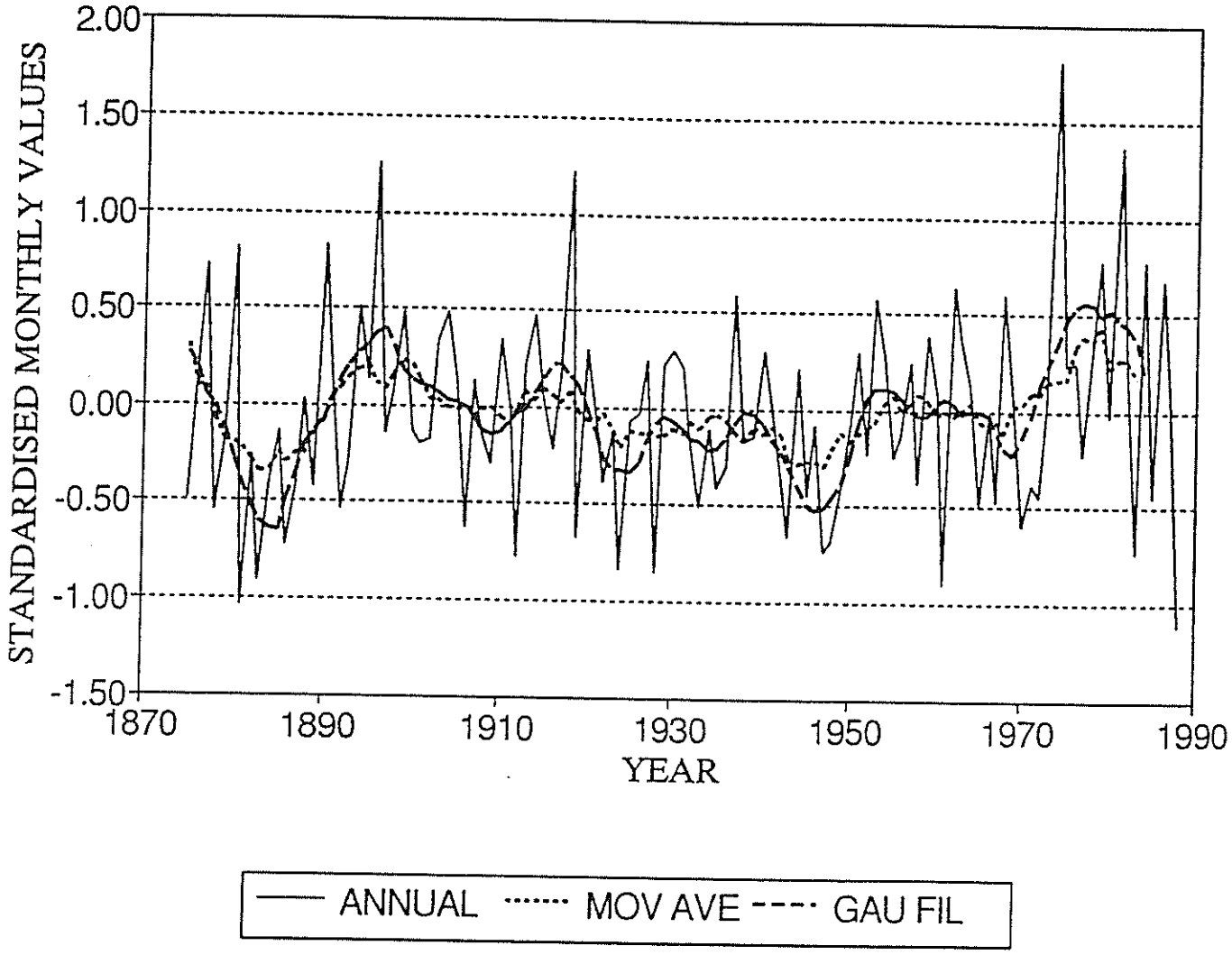


Fig B9 Plot of January rainfall time series with 11 year moving average and 11 point Gaussian filter for summer tropical region.

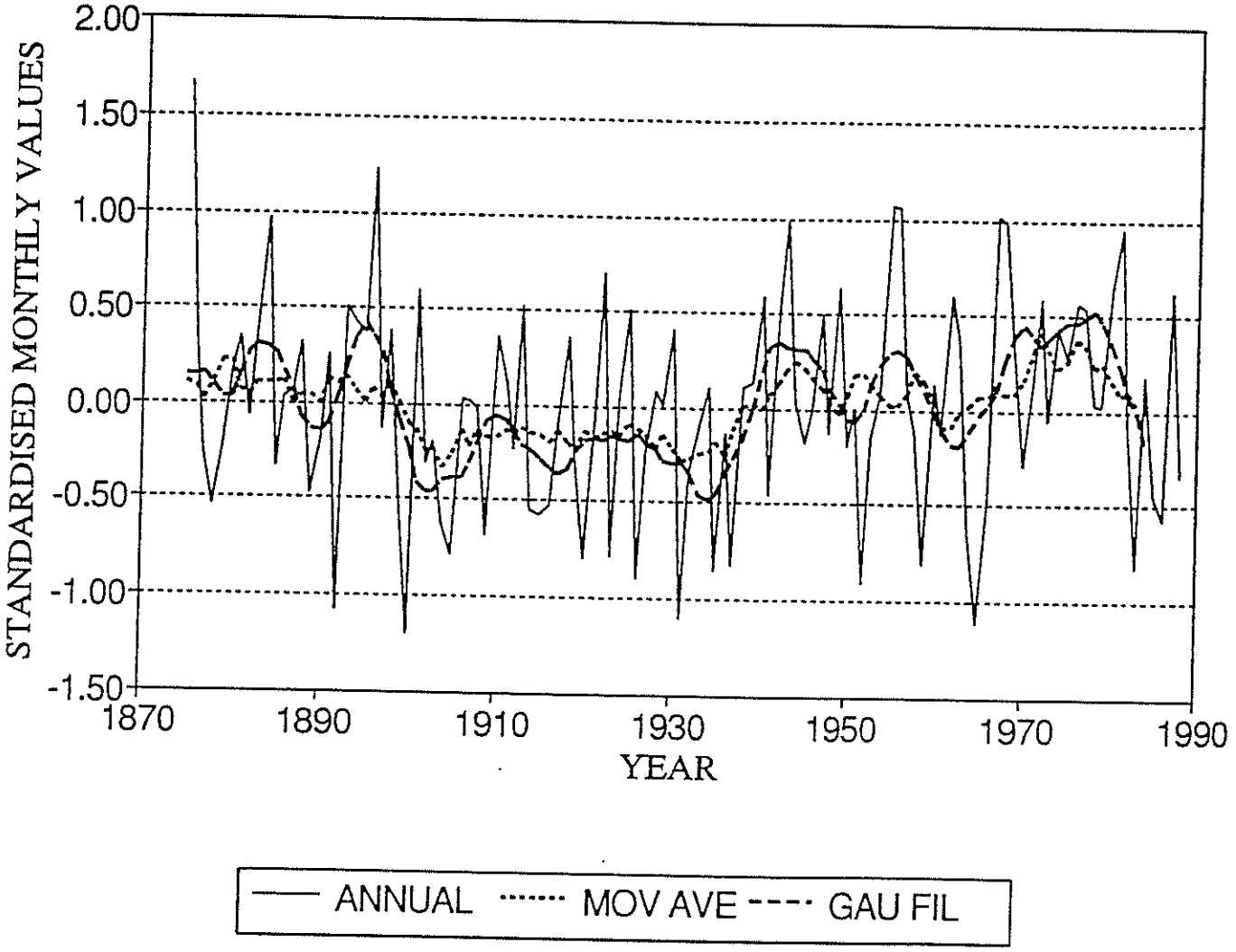
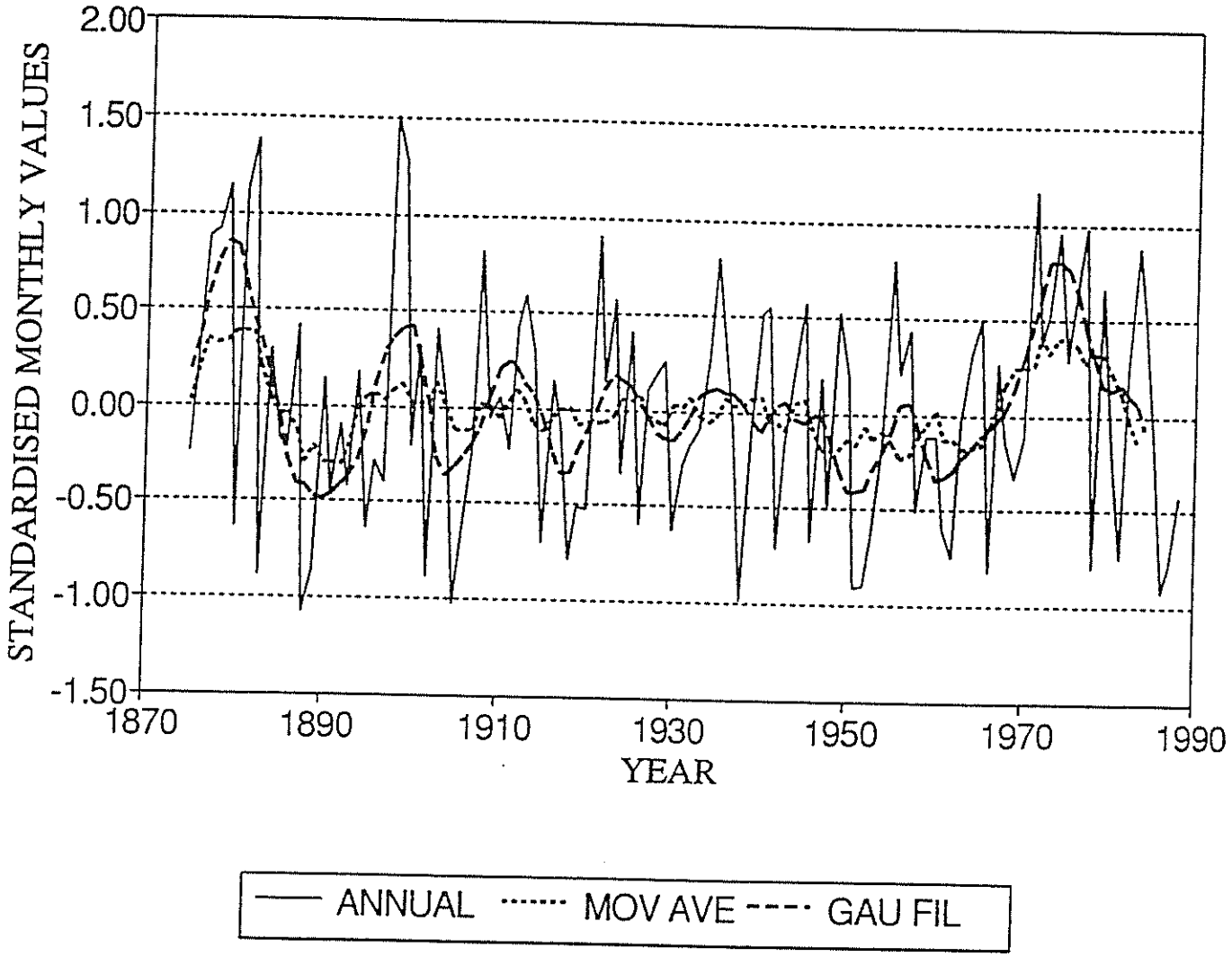


Fig B10 Plot of February rainfall time series with 11 year moving average and 11 point Gaussian filter for summer tropical region.



FigB11 Plot of March rainfall time series with 11 year moving average and 11 point Gaussian filter for summer tropical region.

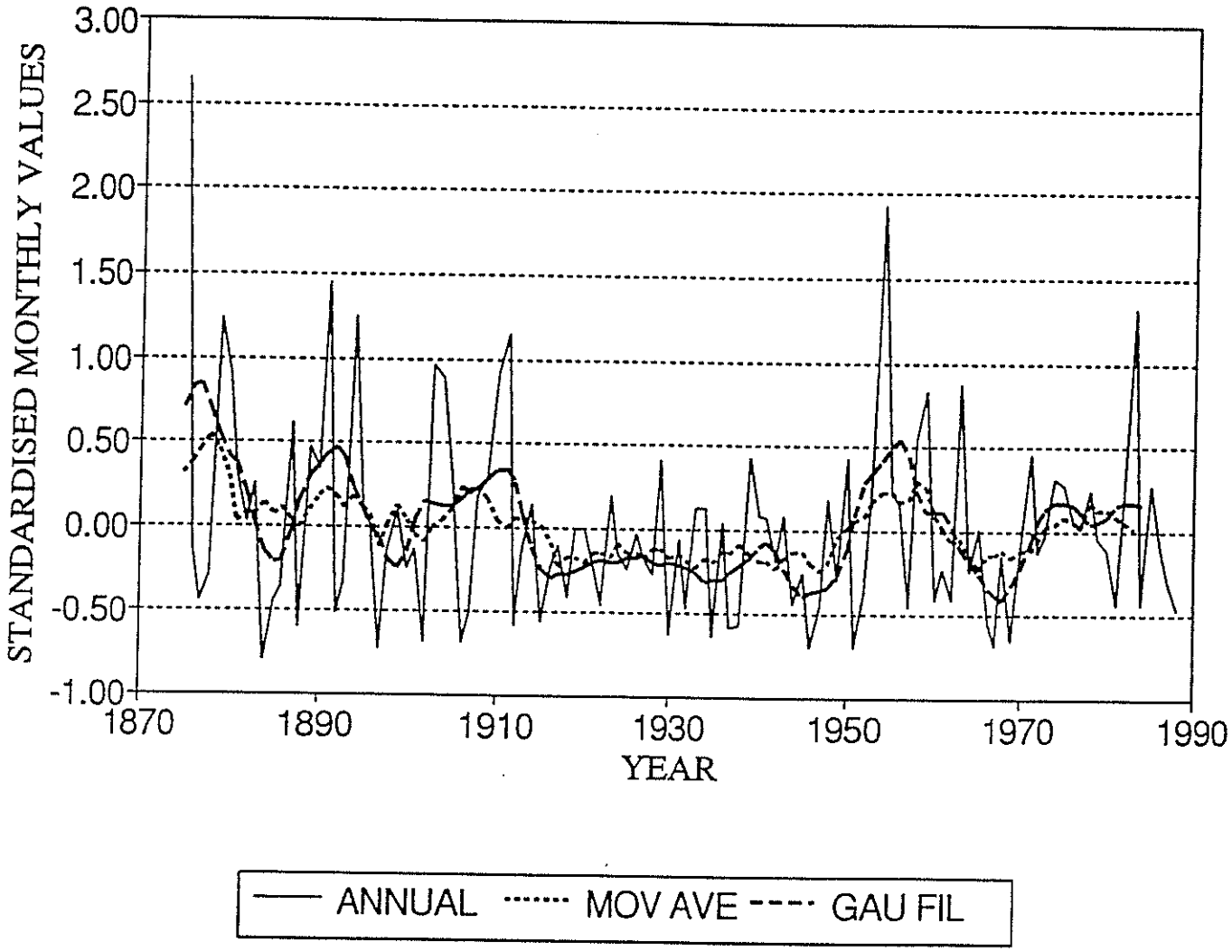


Fig B12 Plot of April rainfall time series with 11 year moving average and 11 point Gaussian filter for summer tropical region.

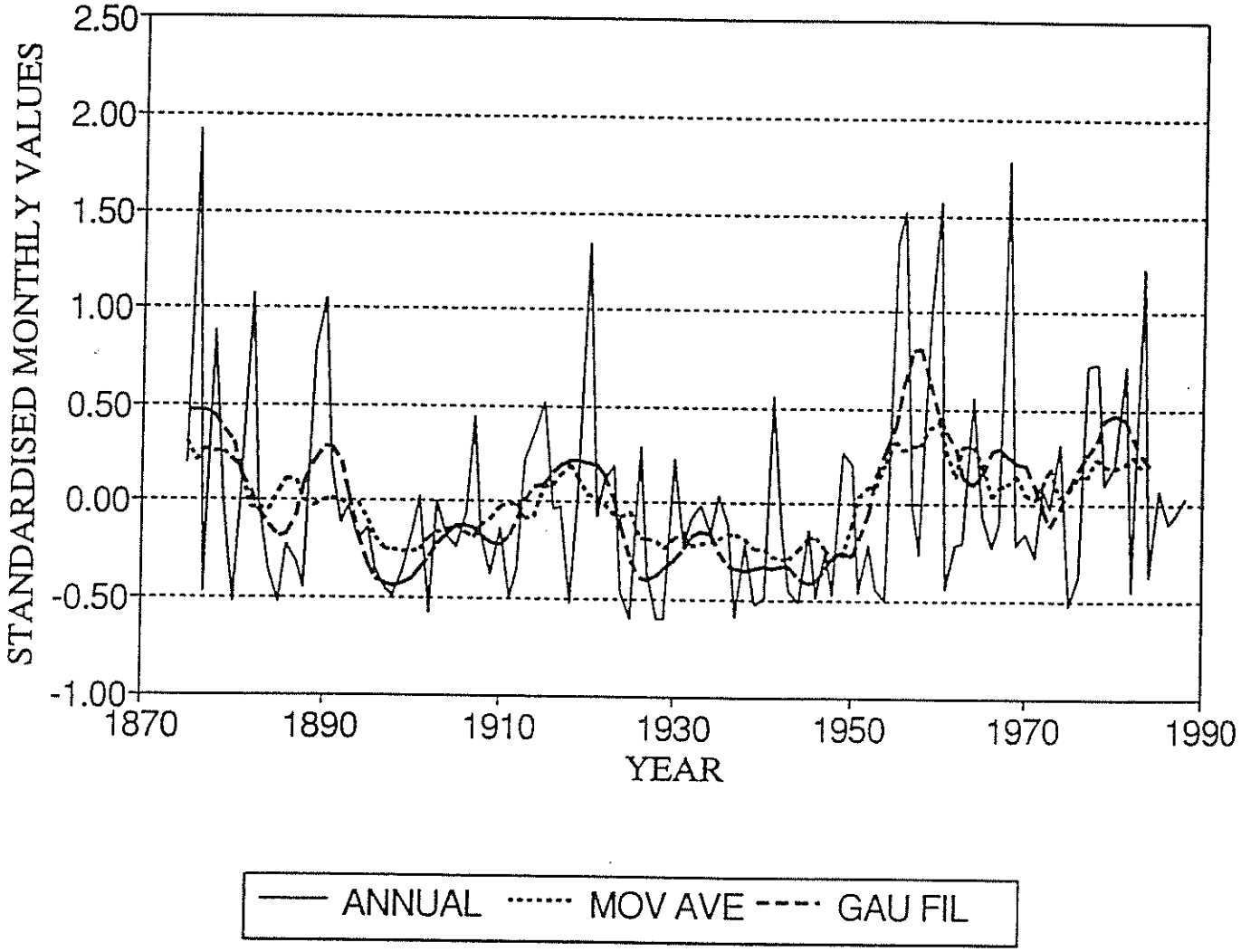


Fig B13 Plot of May rainfall time series with 11 year moving average and 11 point Gaussian filter for summer tropical region.

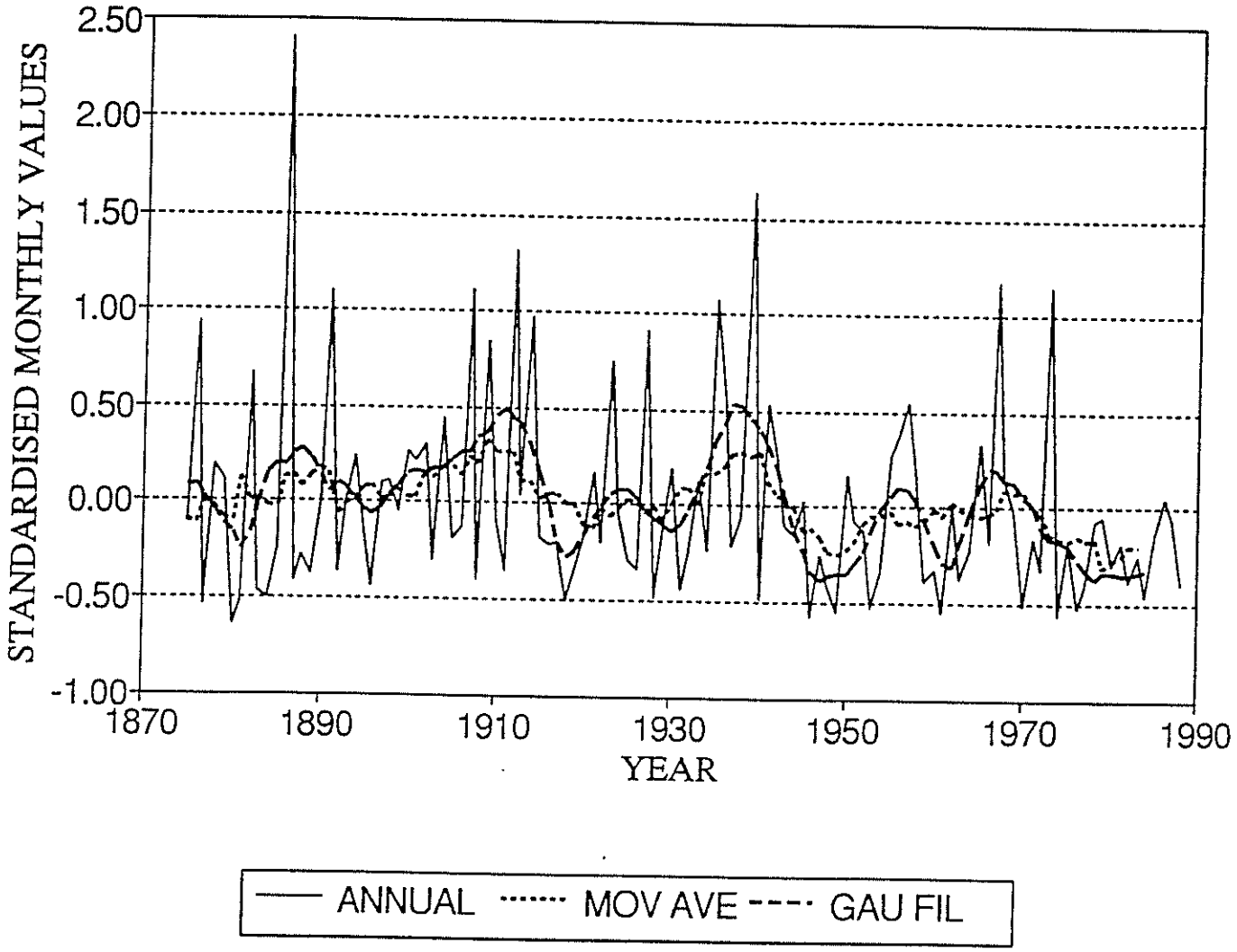


Fig B14 Plot of June rainfall time series with 11 year moving average and 11 point Gaussian filter for summer tropical region.

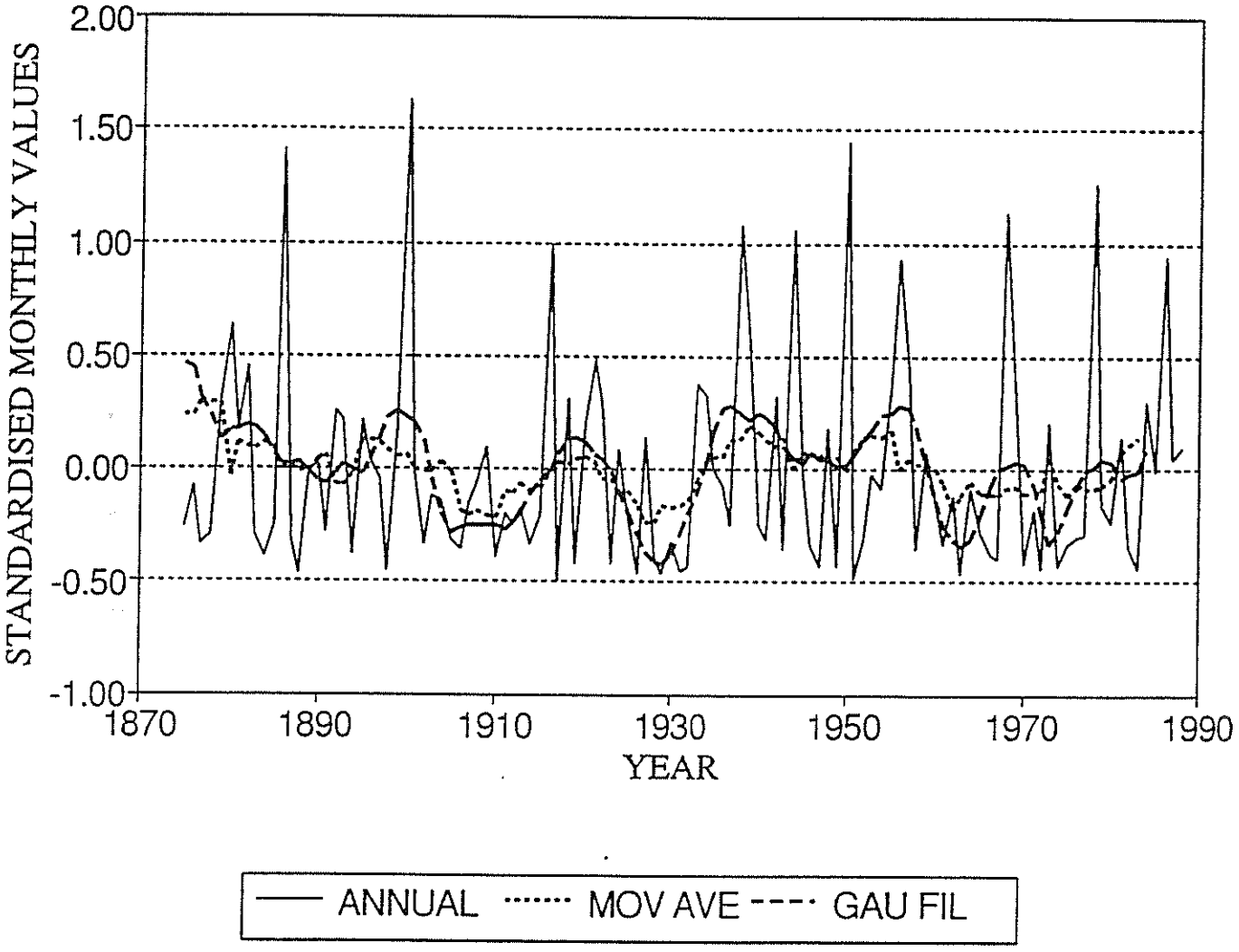


Fig B15 Plot of July rainfall time series with 11 year moving average and 11 point Gaussian filter for summer tropical region.

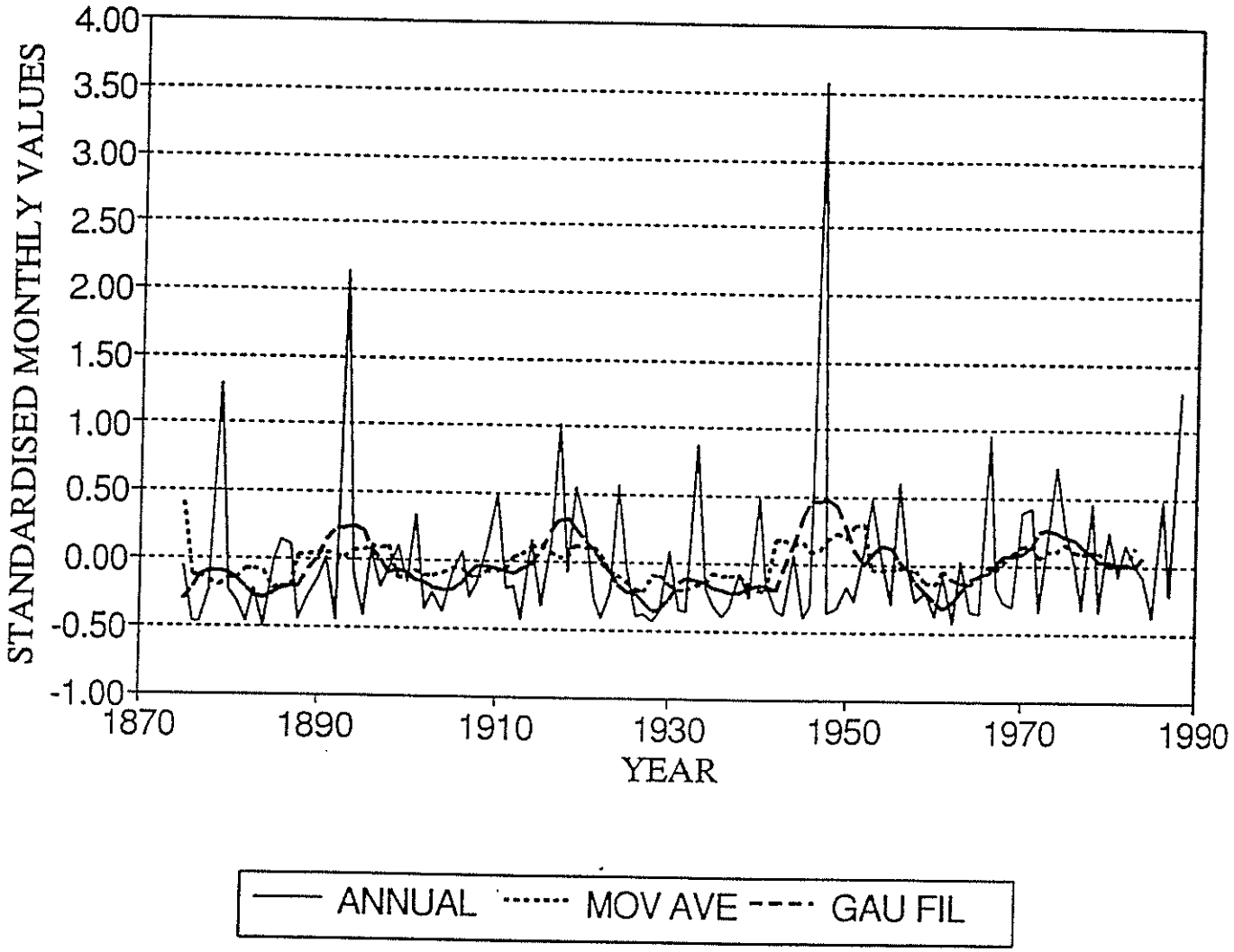


Fig B16 Plot of August rainfall time series with 11 year moving average and 11 point Gaussian filter for summer tropical region.

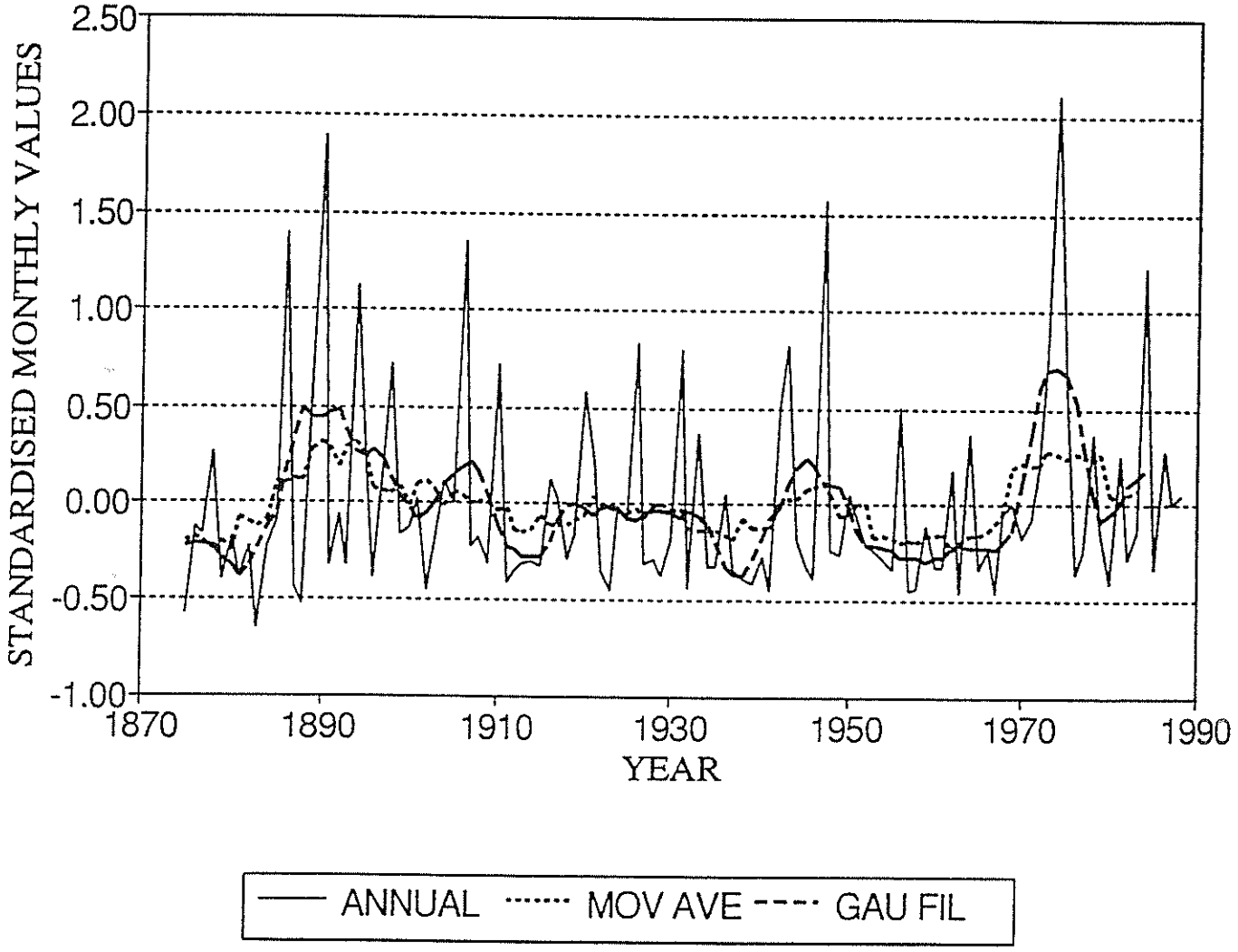


Fig B17 Plot of September rainfall time series with 11 year moving average and 11 point Gaussian filter for summer tropical region.

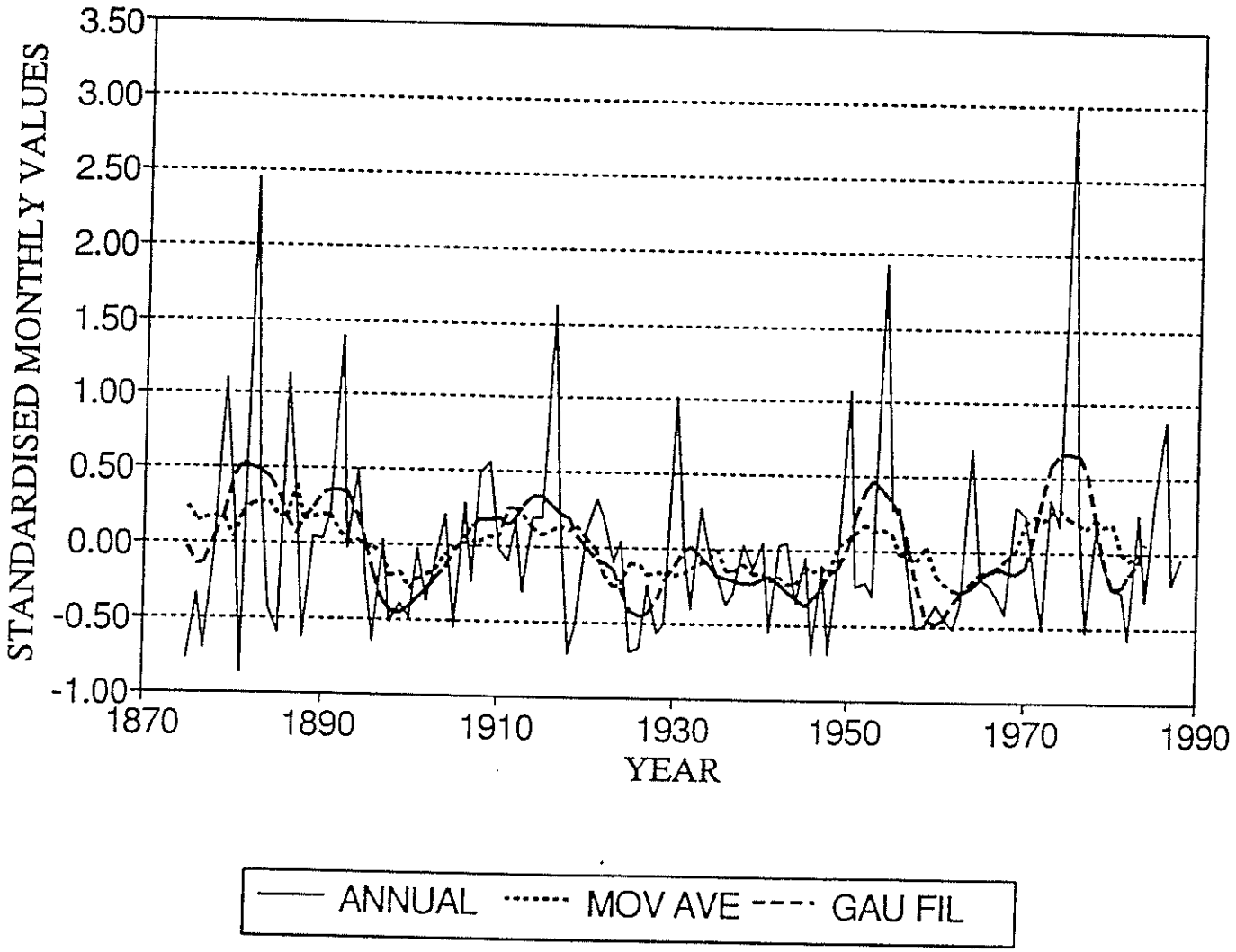


Fig B18 Plot of October rainfall time series with 11 year moving average and 11 point Gaussian filter for summer tropical region.

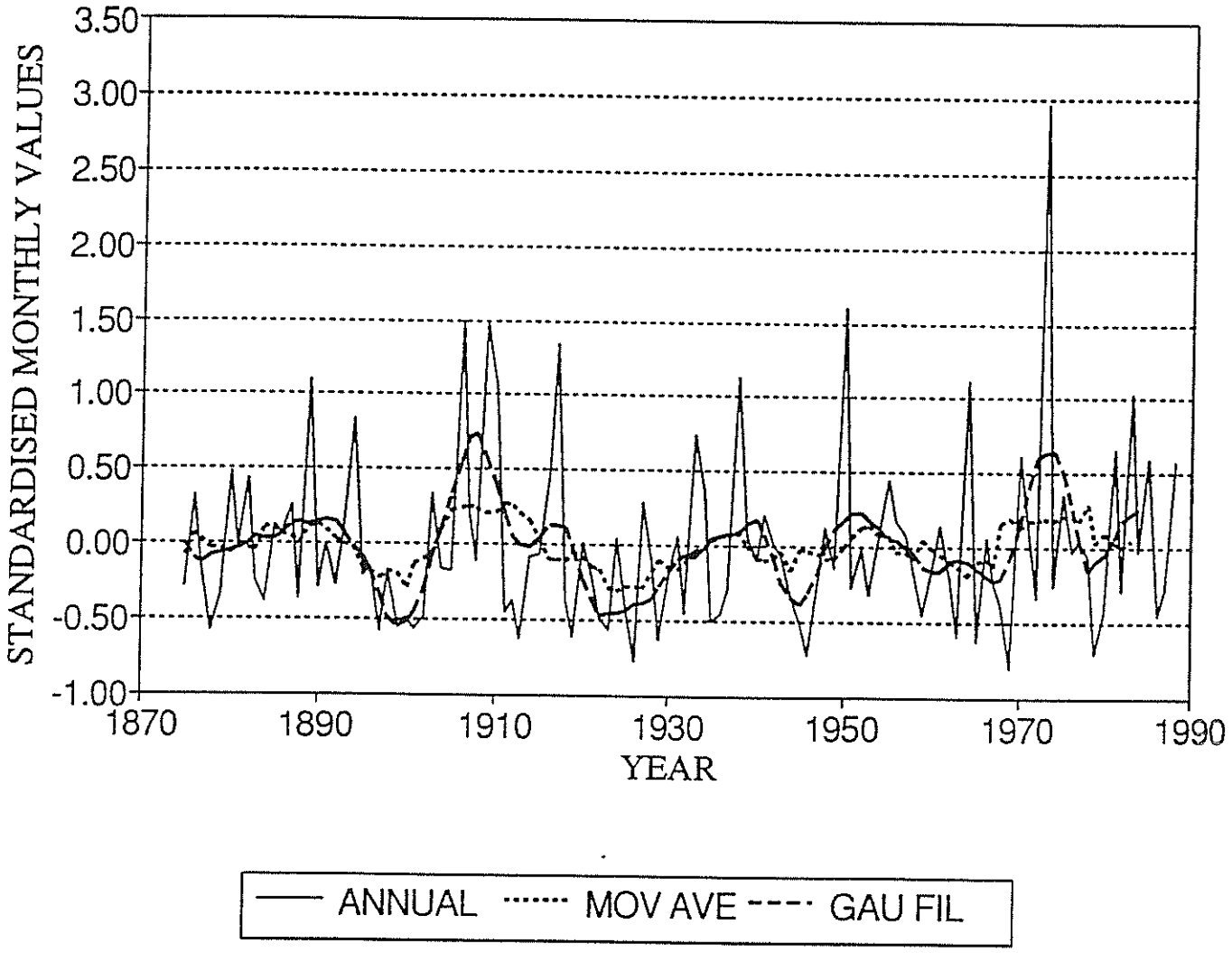


Fig B19 Plot of November rainfall time series with 11 year moving average and 11 point Gaussian filter for summer tropical region.

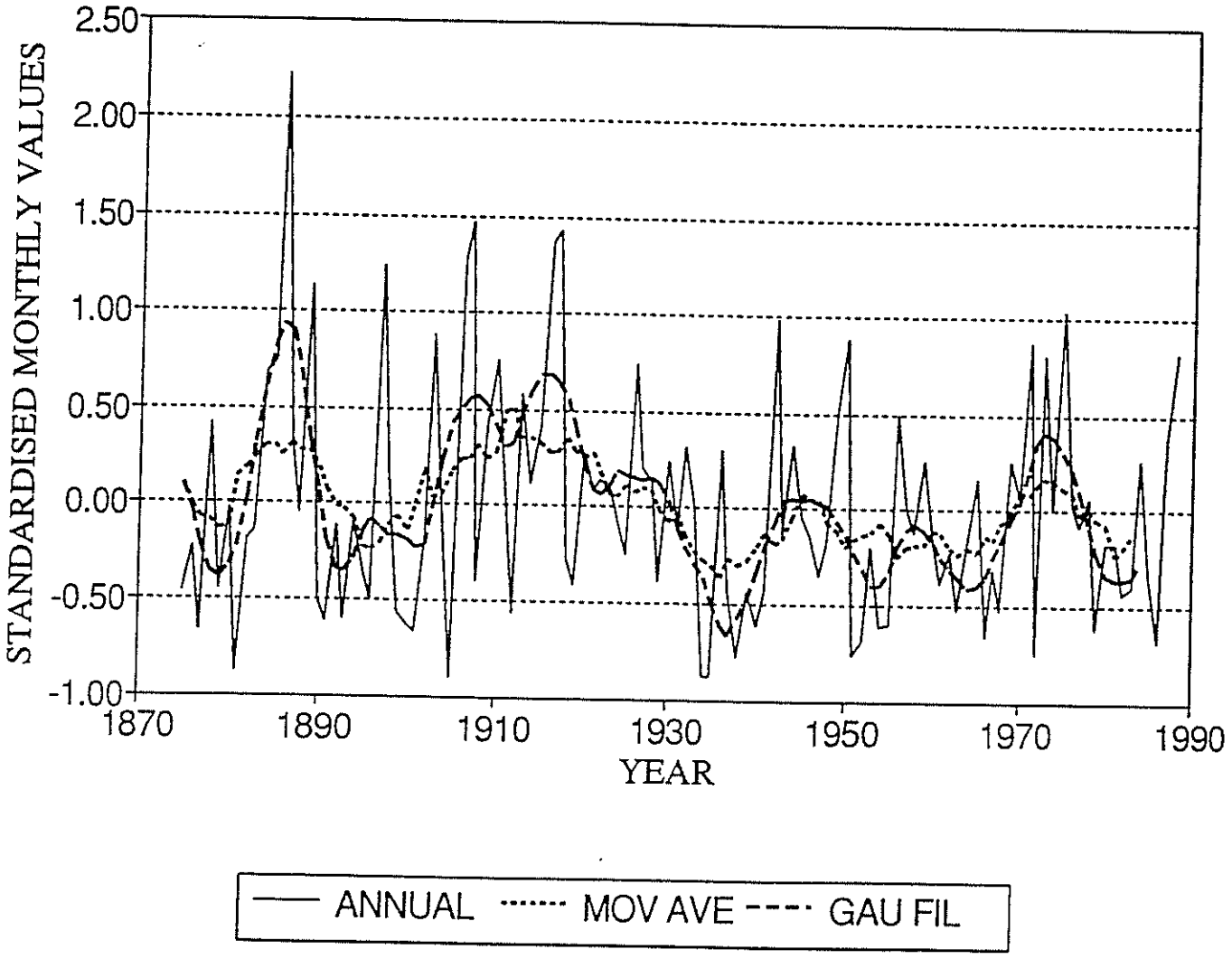


Fig B20 Plot of December rainfall time series with 11 year moving average and 11 point Gaussian filter for summer tropical region.

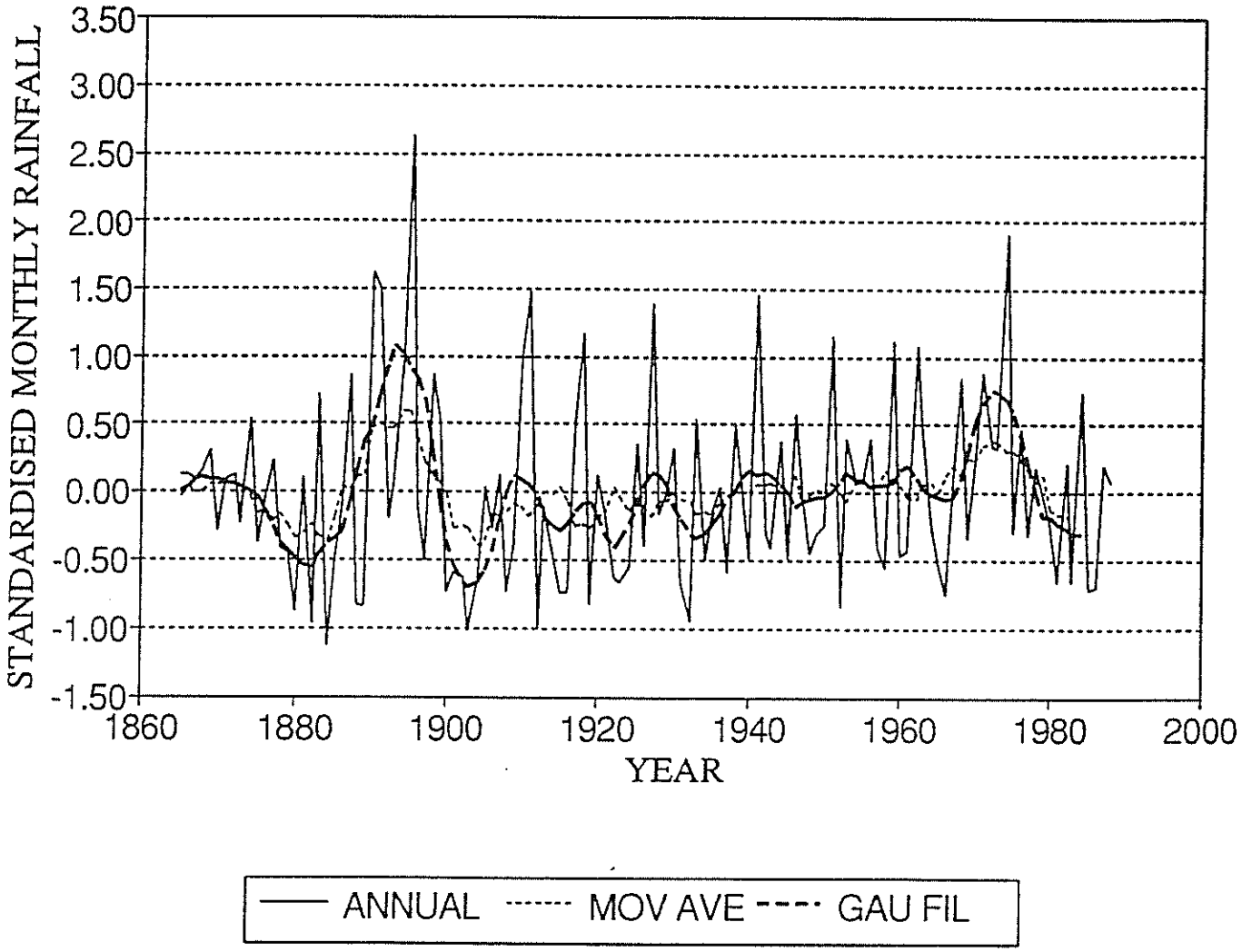


Fig B21 Plot of January rainfall time series with 11 year moving average and 11 point Gaussian filter for summer subtropical region.

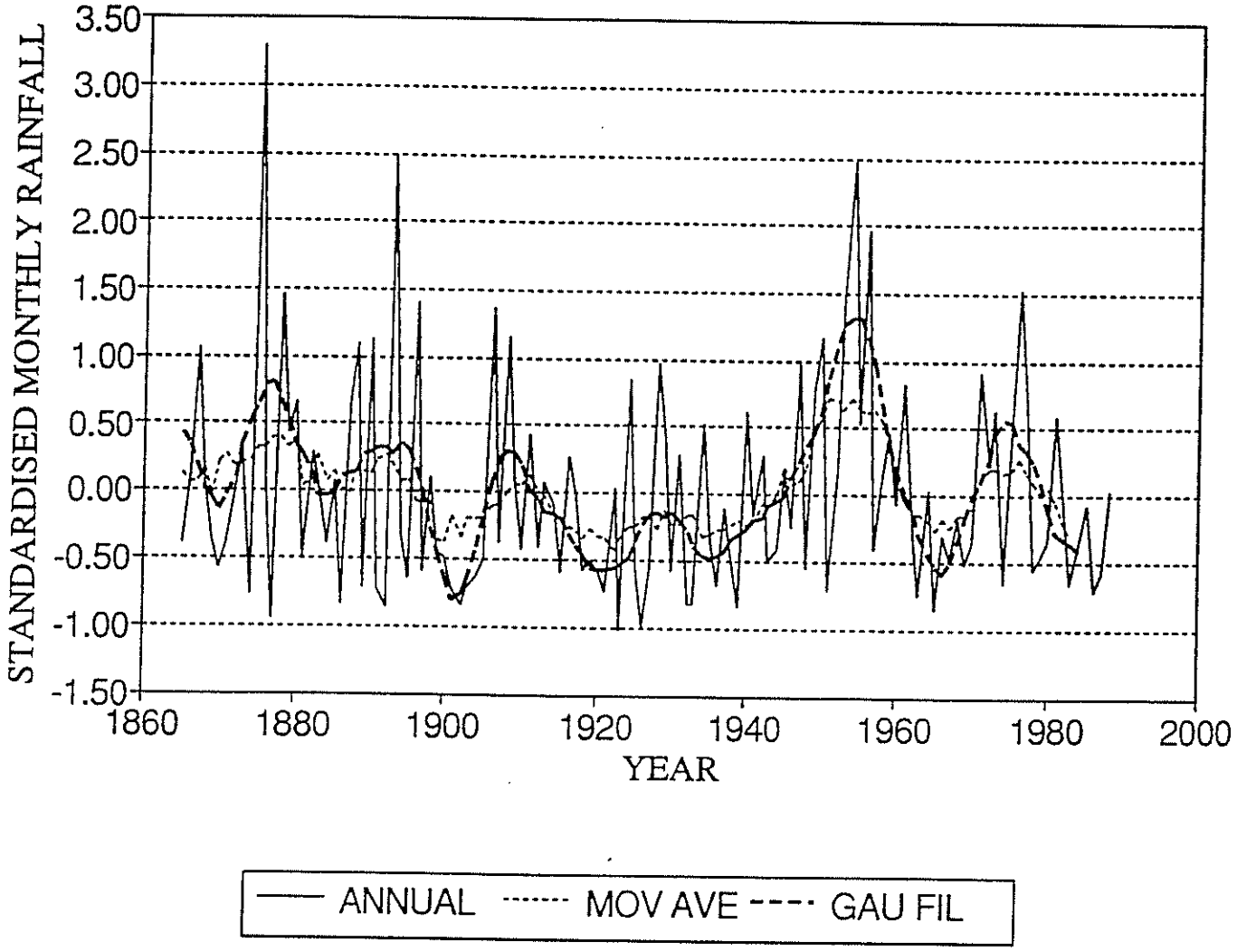


Fig B22 Plot of February rainfall time series with 11 year moving average and 11 point Gaussian filter for summer subtropical region.

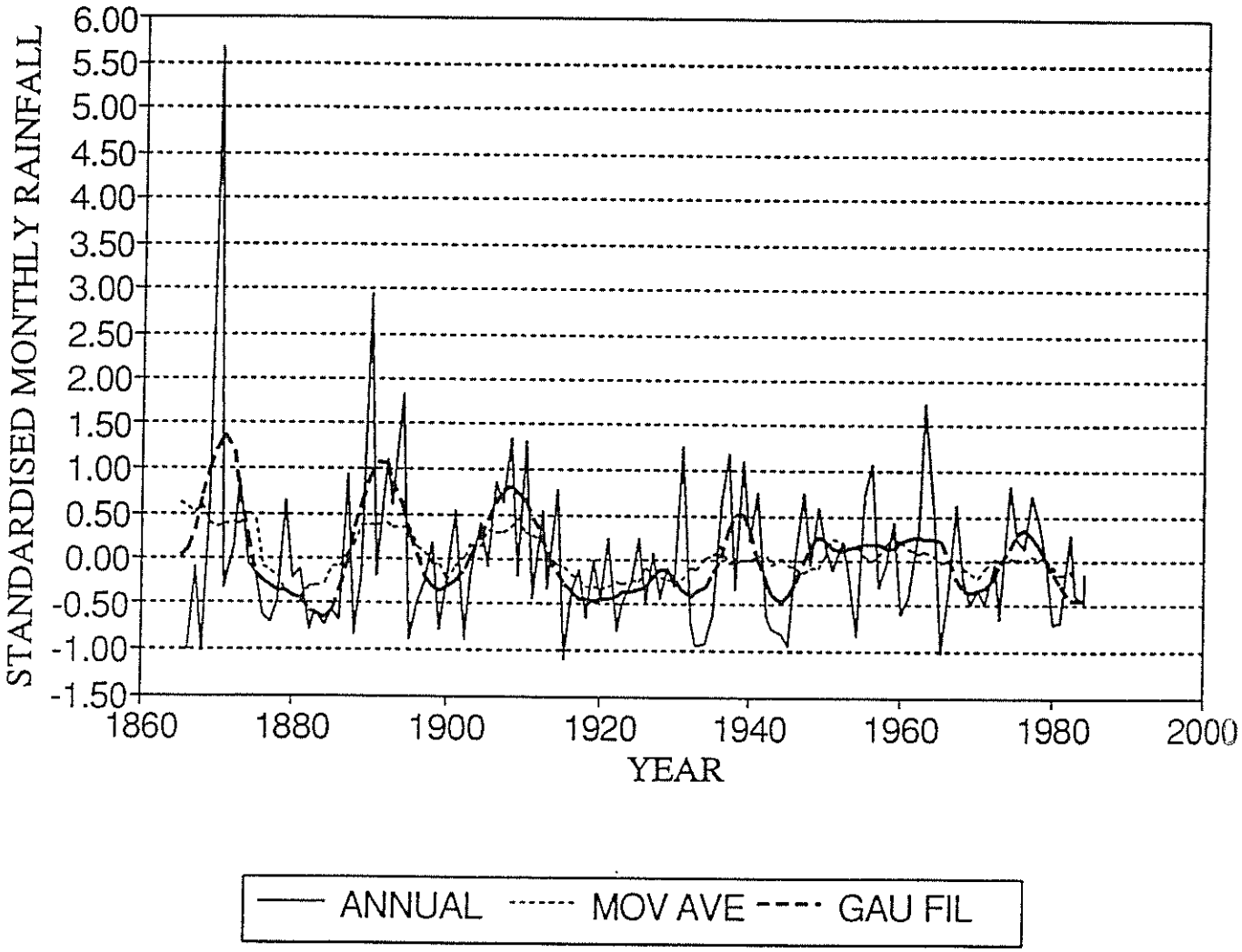


Fig B23 Plot of March rainfall time series with 11 year moving average and 11 point Gaussian filter for summer subtropical region.

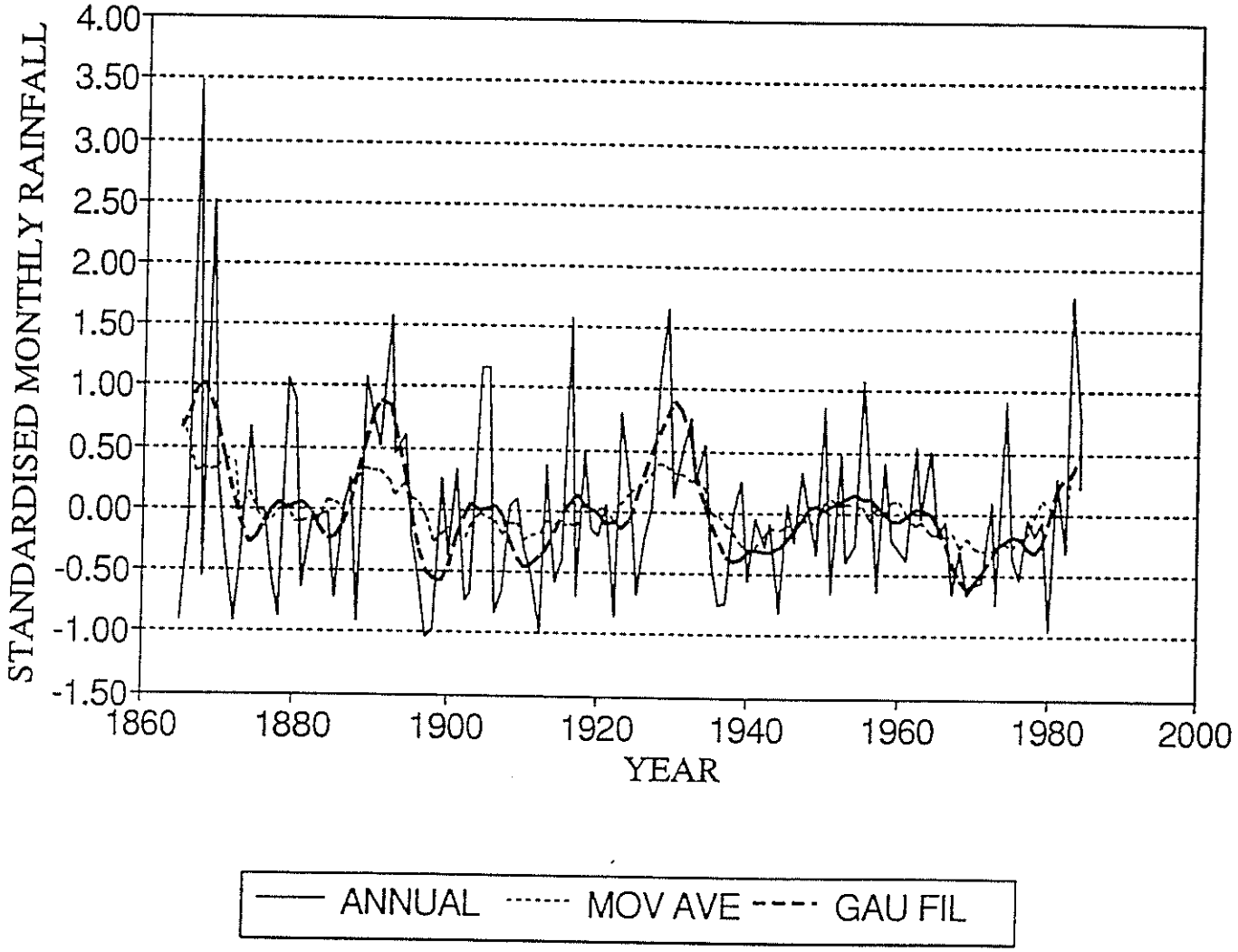


Fig B24 Plot of April rainfall time series with 11 year moving average and 11 point Gaussian filter for summer subtropical region.

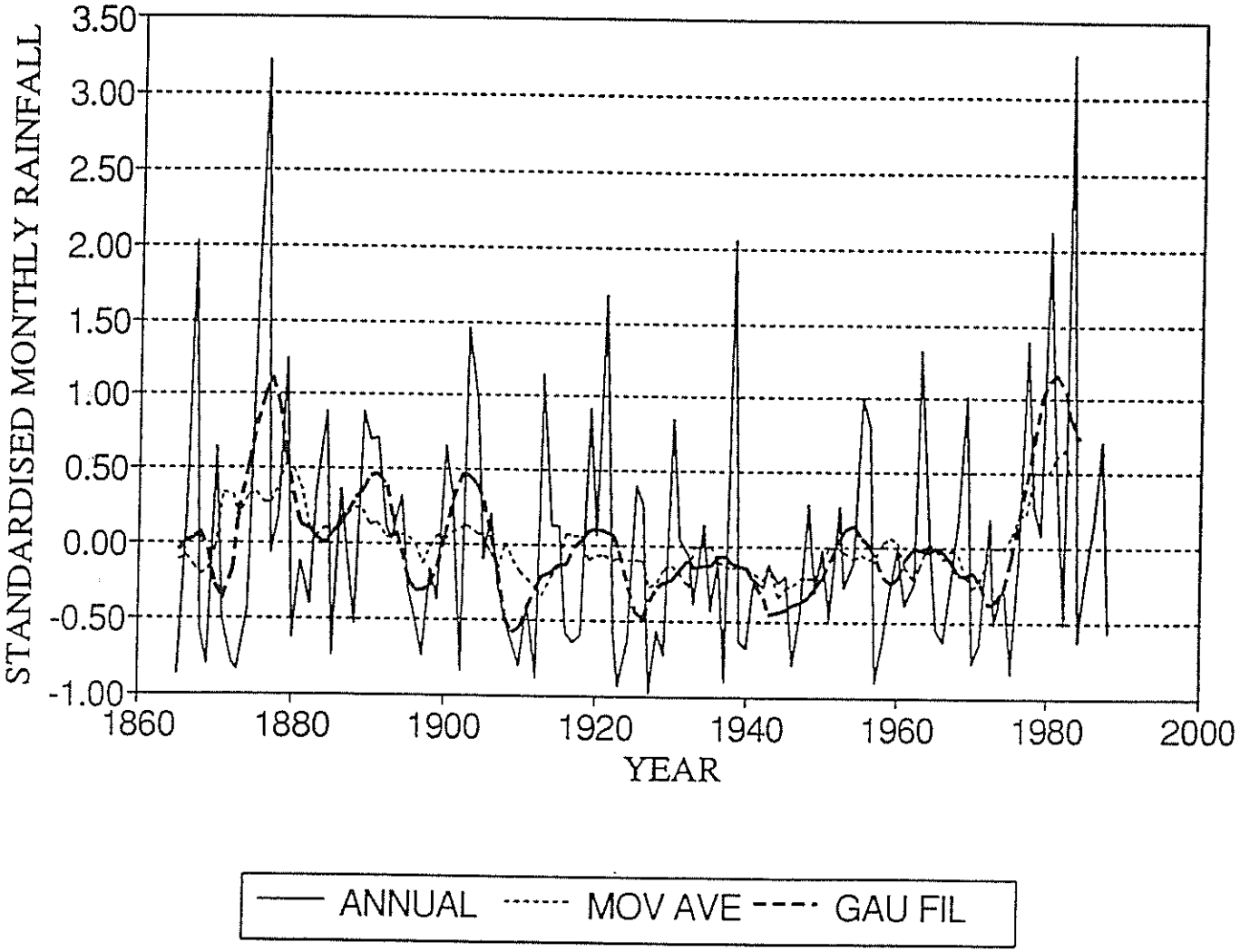


Fig B25 Plot of May rainfall time series with 11 year moving average and 11 point Gaussian filter for summer subtropical region.

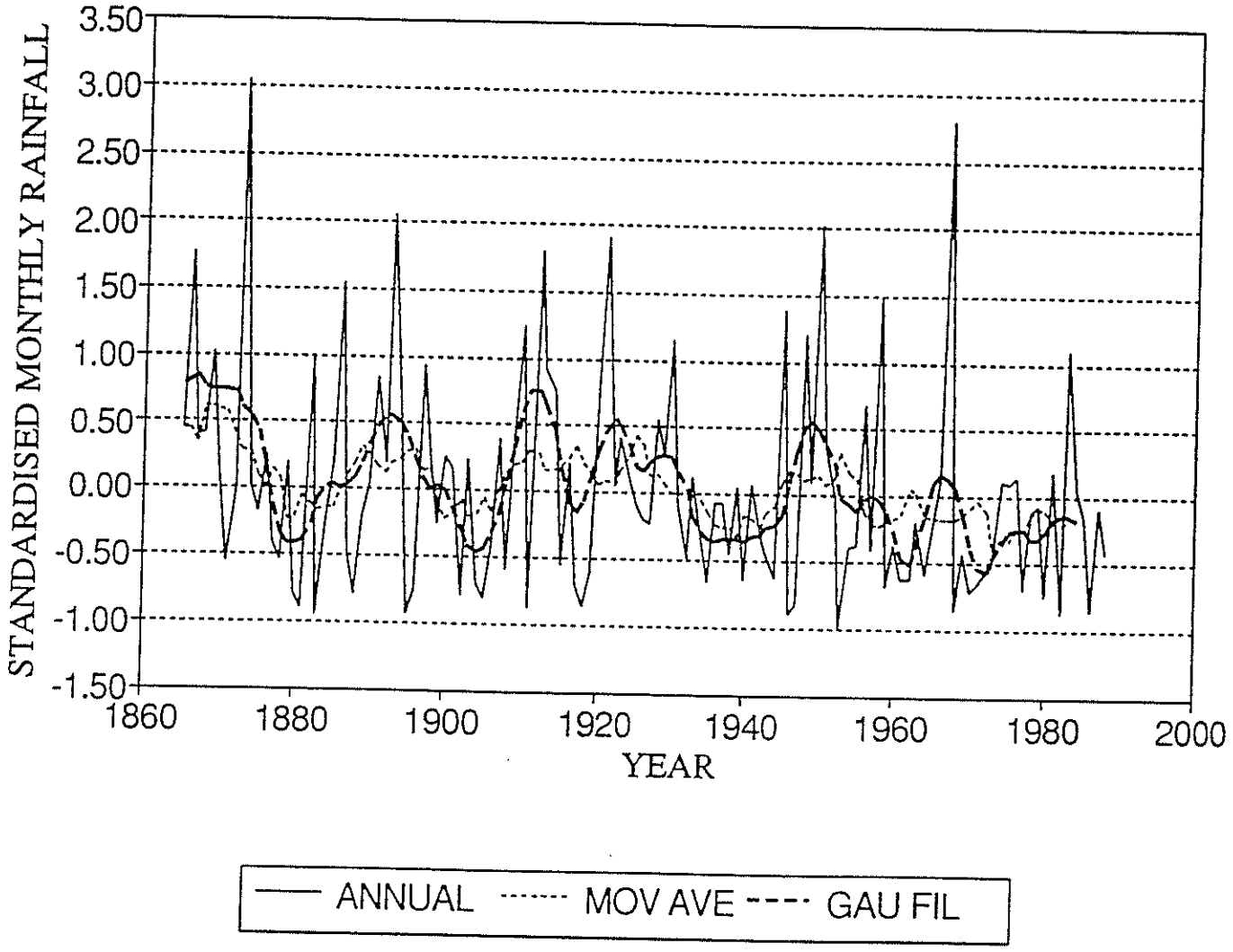


Fig B26 Plot of June rainfall time series with 11 year moving average and 11 point Gaussian filter for summer subtropical region.

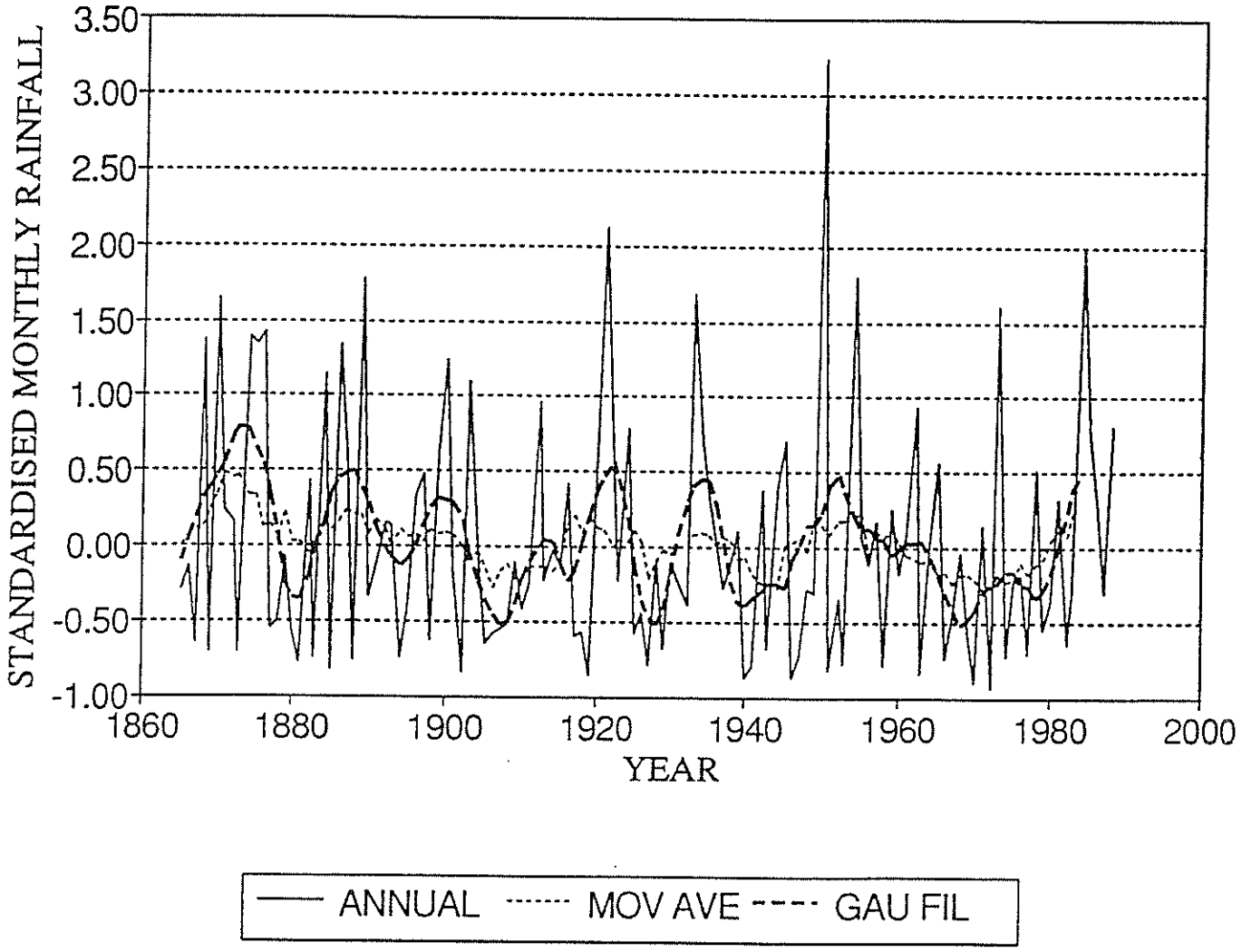


Fig B27 Plot of July rainfall time series with 11 year moving average and 11 point Gaussian filter for summer subtropical region.

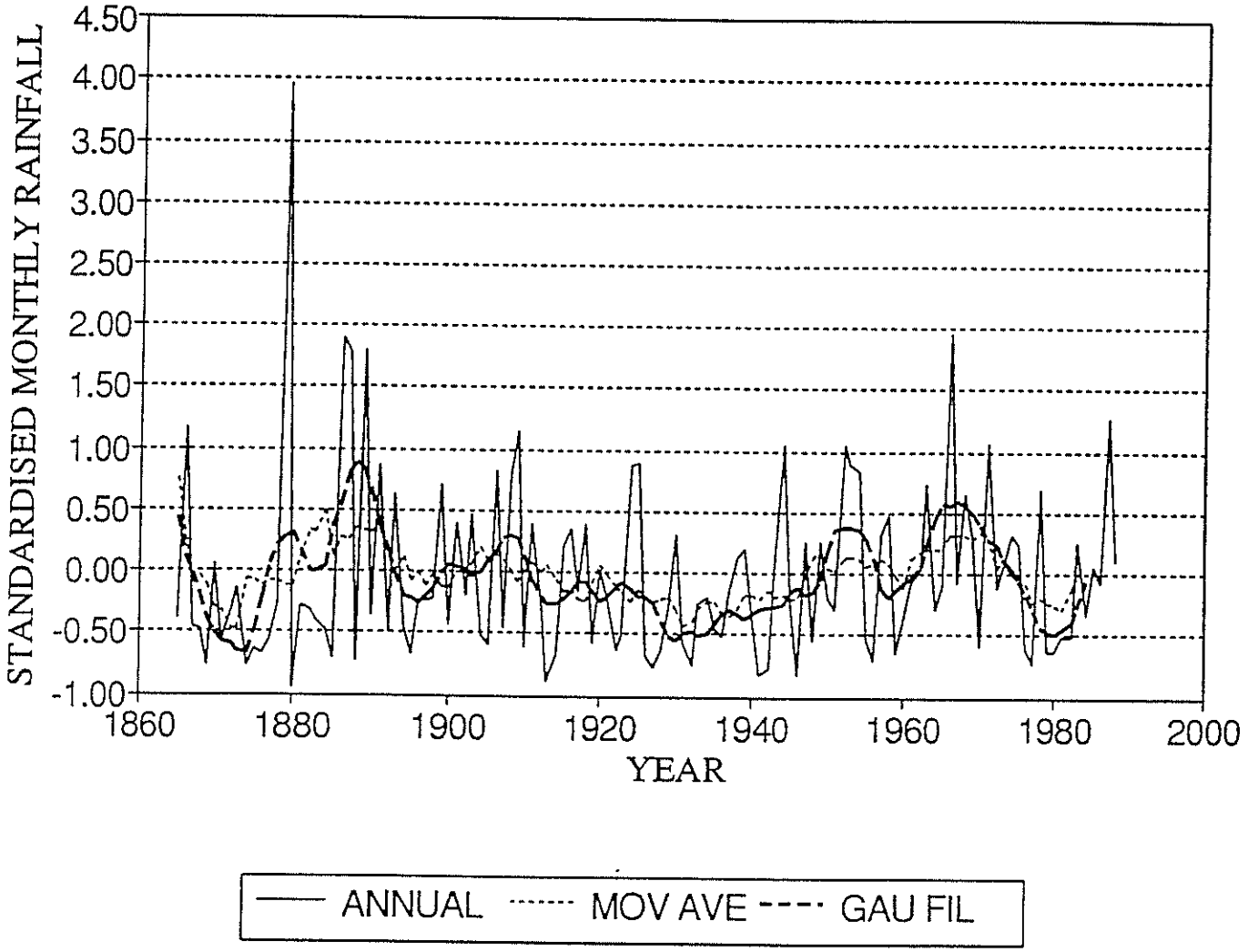


Fig B28 Plot of August rainfall time series with 11 year moving average and 11 point Gaussian filter for summer subtropical region.

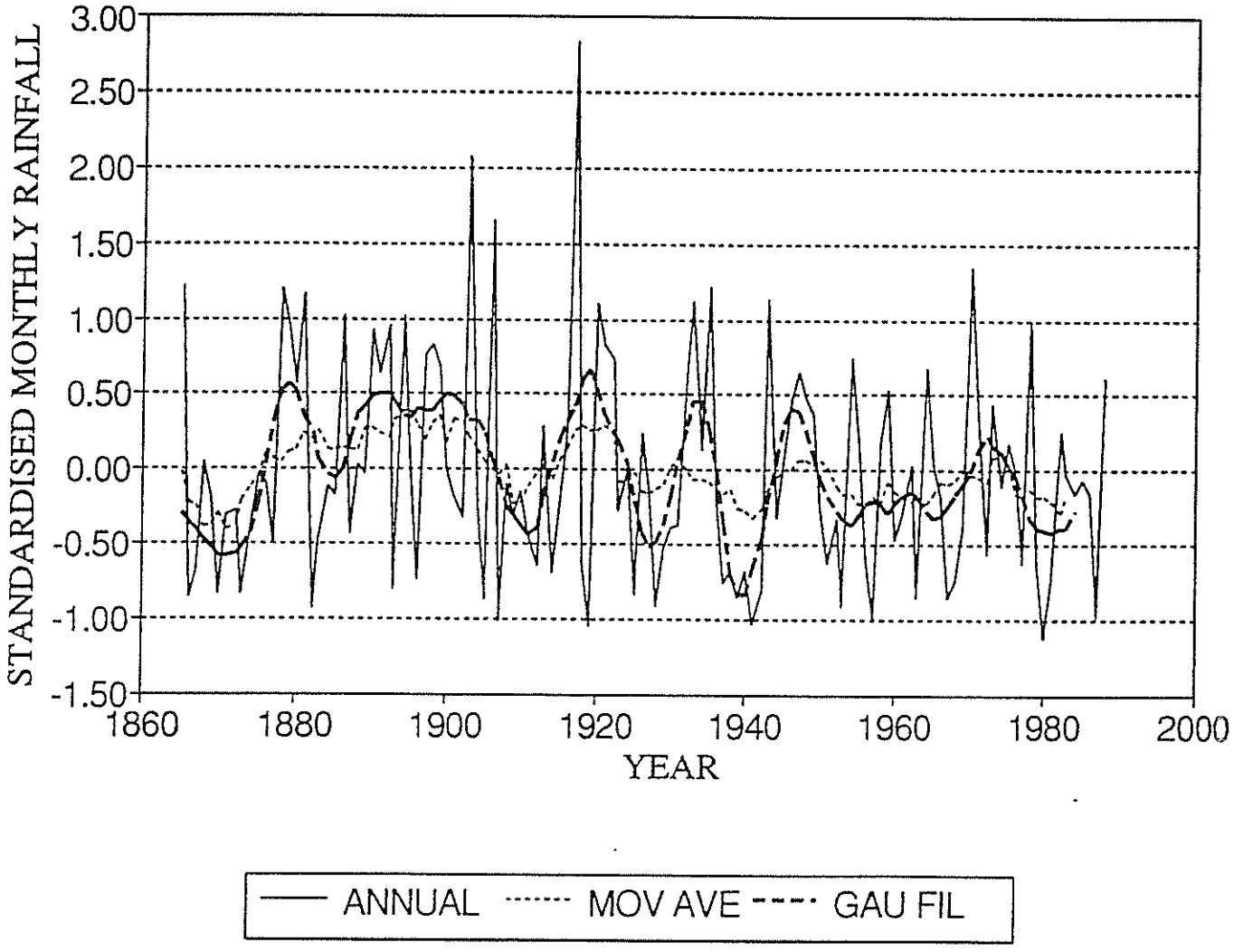


Fig B29 Plot of September rainfall time series with 11 year moving average and 11 point Gaussian filter for summer subtropical region.

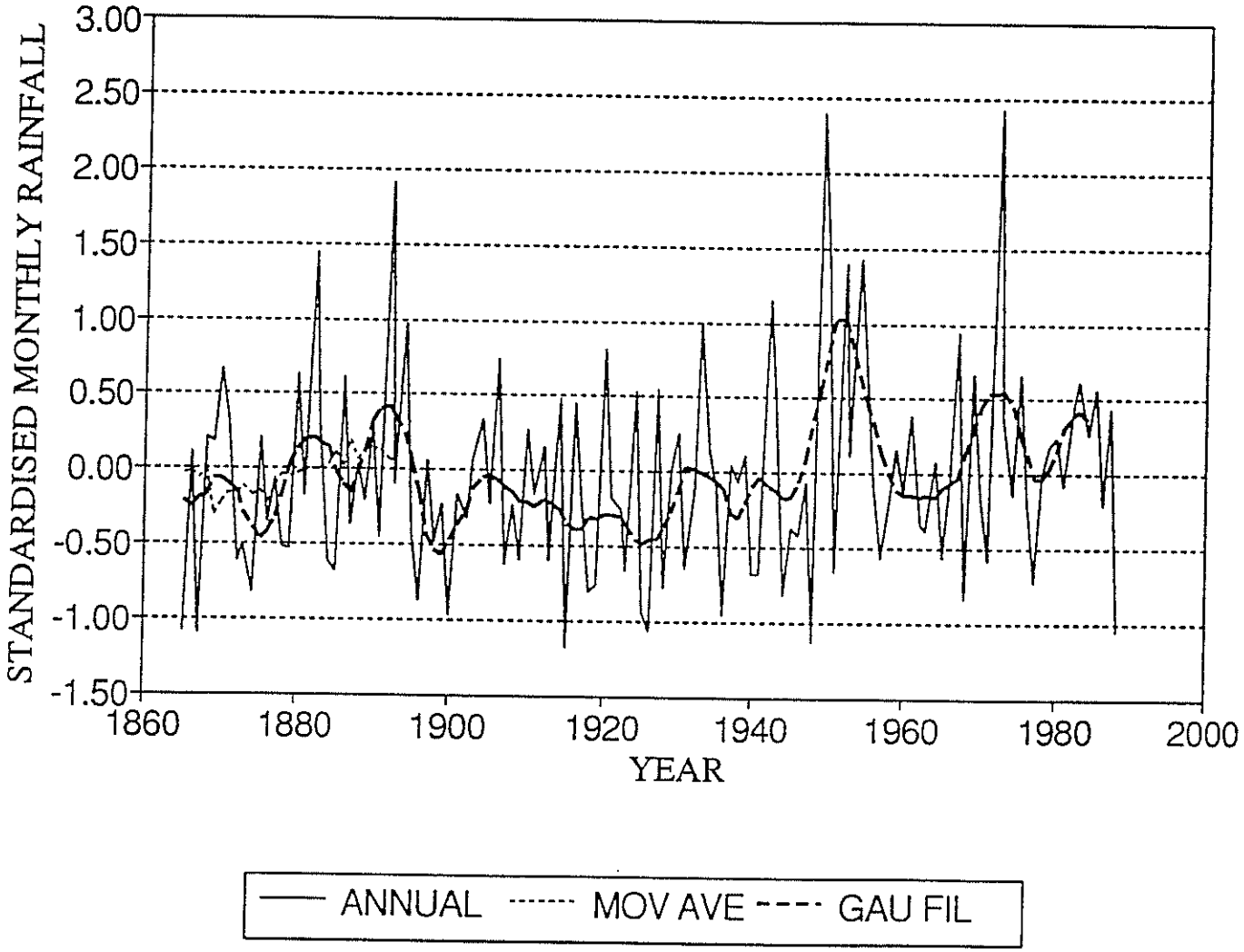


Fig B30 Plot of October rainfall time series with 11 year moving average and 11 point Gaussian filter for summer subtropical region.

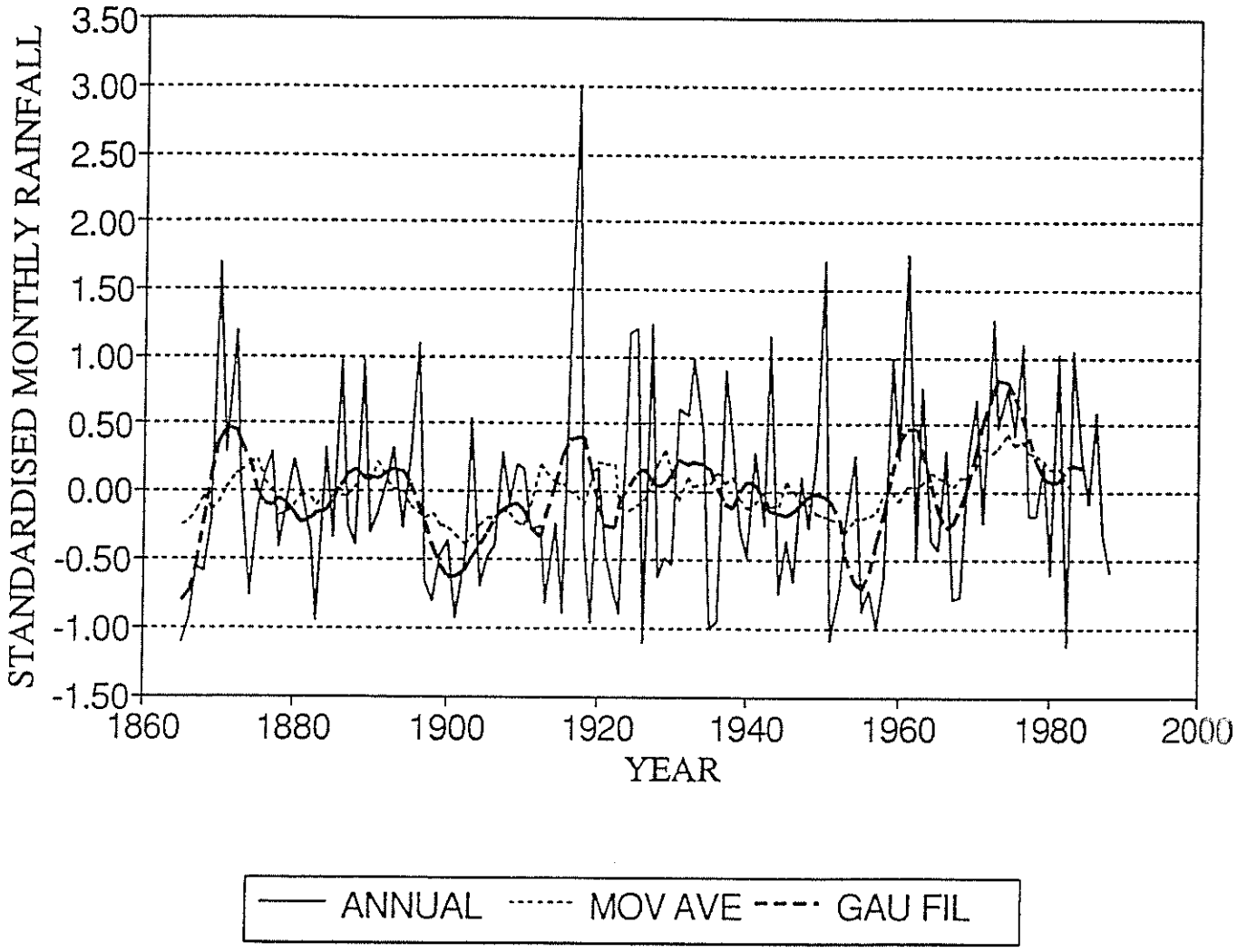


Fig B31 Plot of November rainfall time series with 11 year moving average and 11 point Gaussian filter for summer subtropical region.

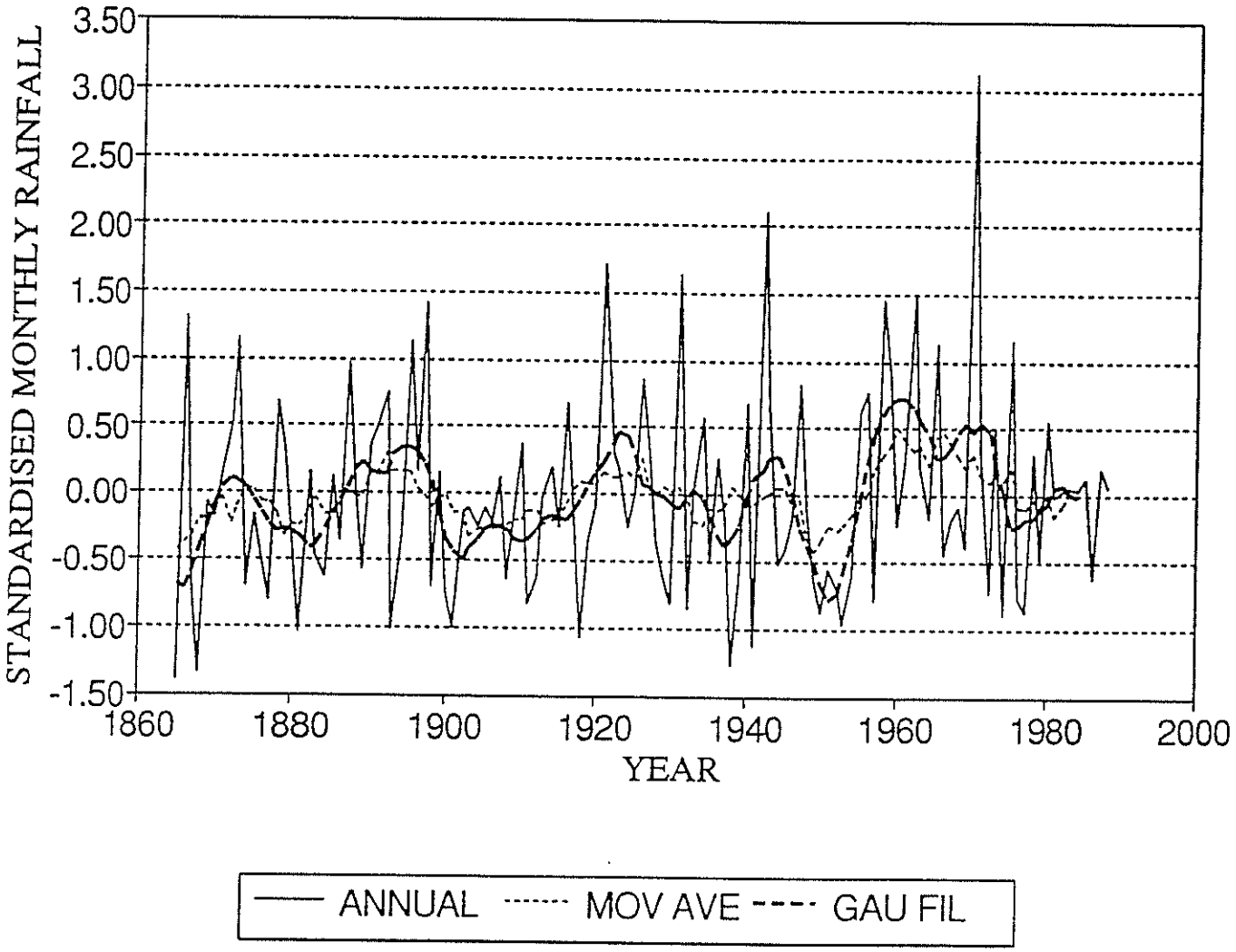


Fig B32 Plot of December rainfall time series with 11 year moving average and 11 point Gaussian filter for summer subtropical region.

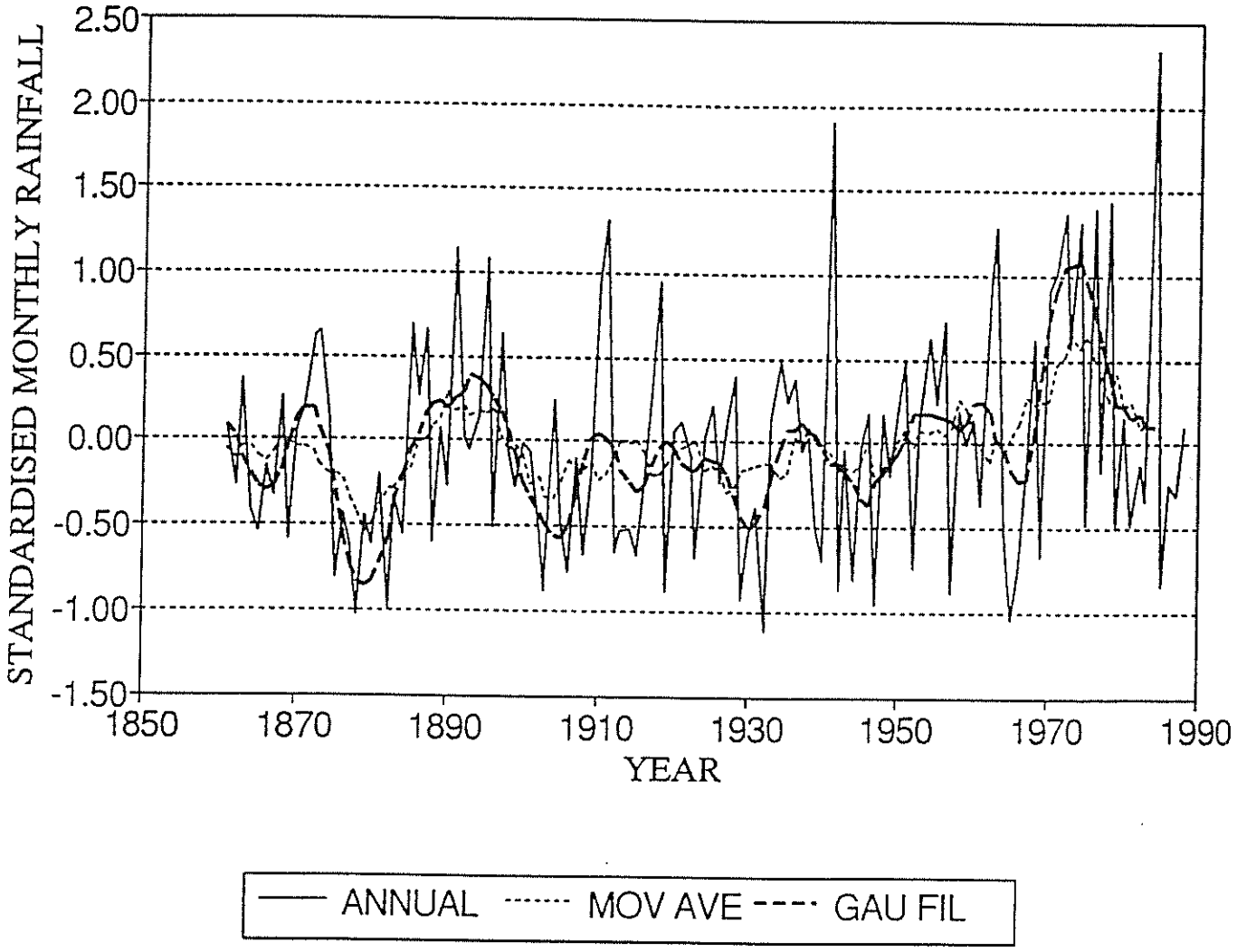


Fig B33 Plot of January rainfall time series with 11 year moving average and 11 point Gaussian filter for uniform temperate region.

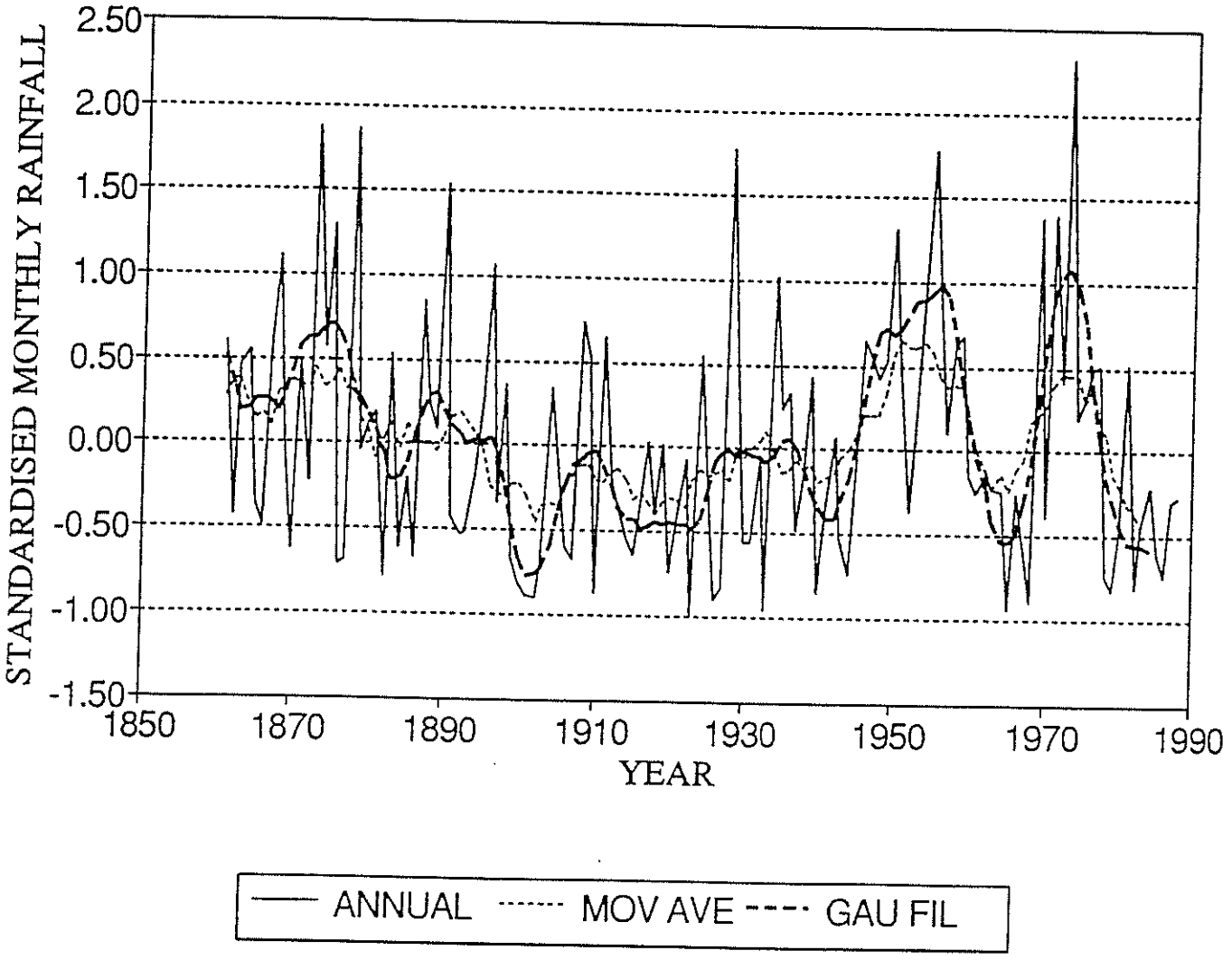


Fig B34 Plot of February rainfall time series with 11 year moving average and 11 point Gaussian filter for uniform temperate region.

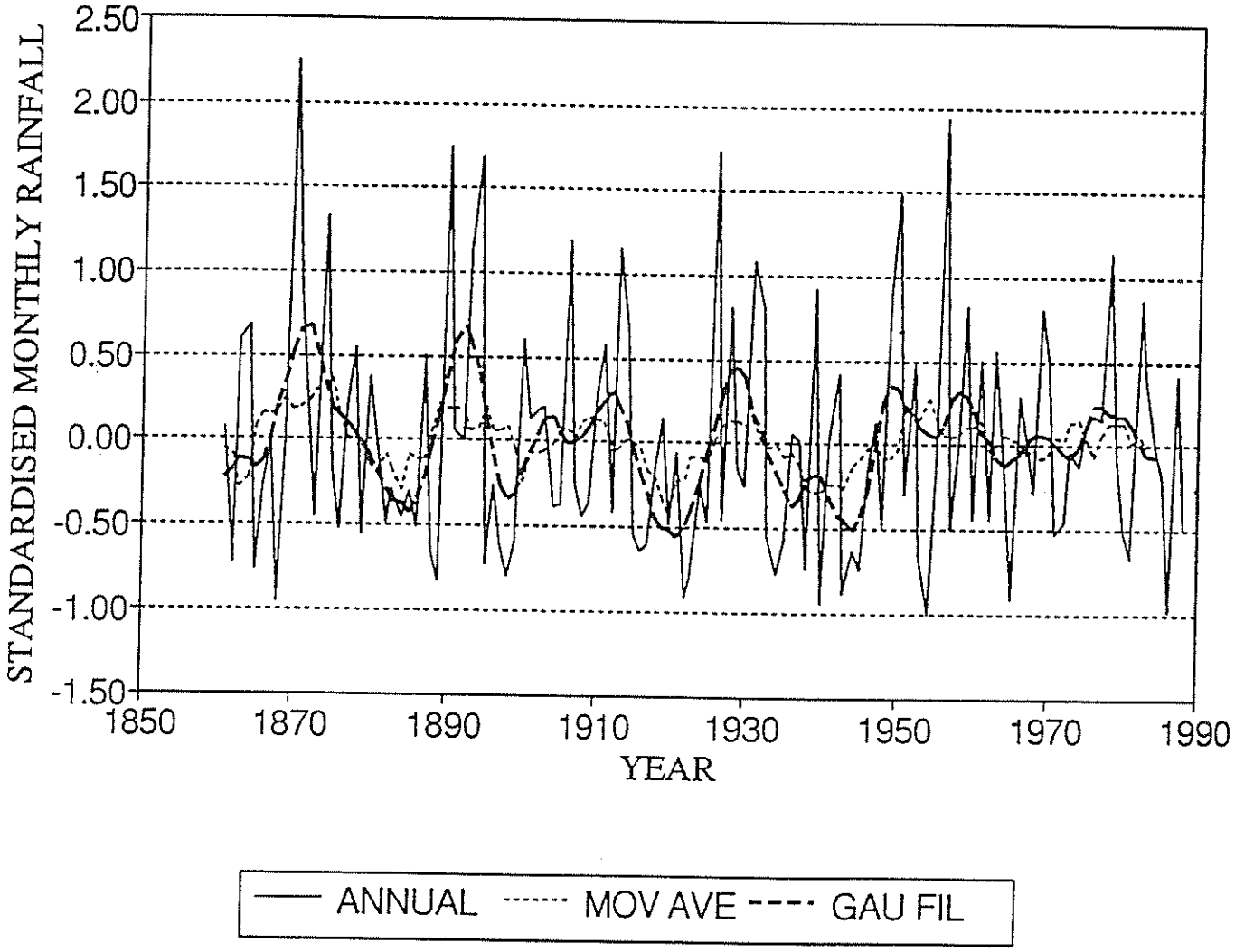


Fig B35 Plot of March rainfall time series with 11 year moving average and 11 point Gaussian filter for uniform temperate region.

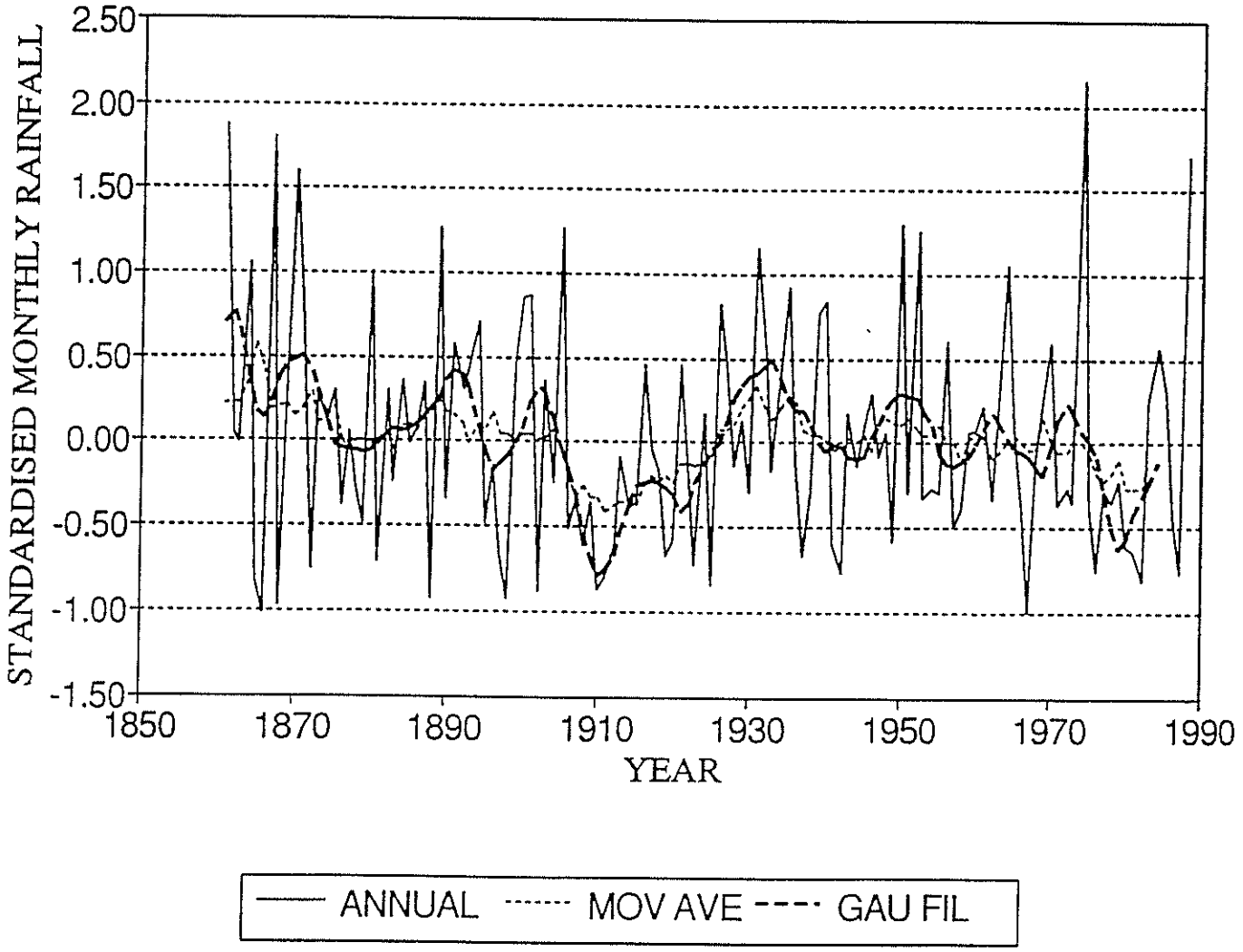


Fig B36 Plot of April rainfall time series with 11 year moving average and 11 point Gaussian filter for uniform temperate region.

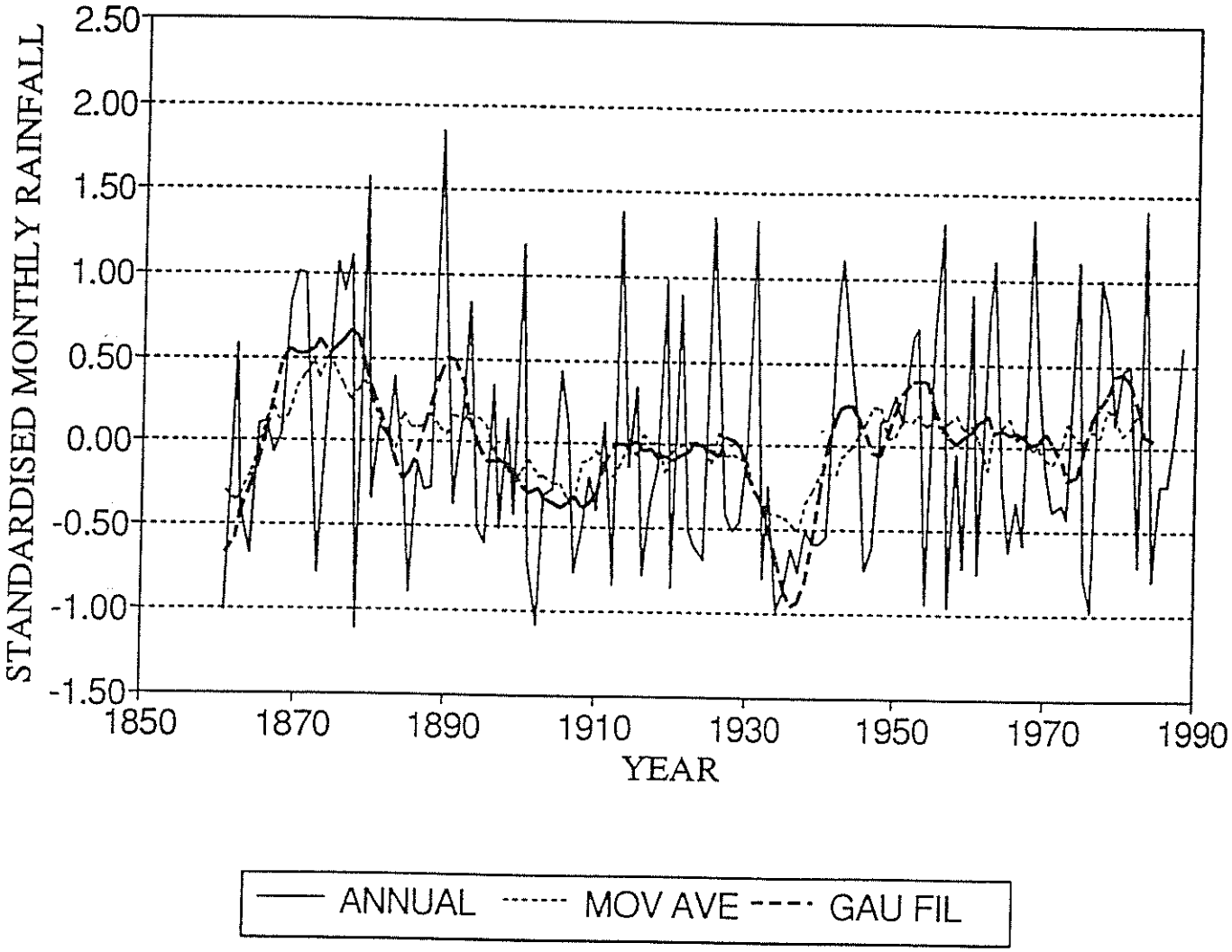


Fig B37 Plot of May rainfall time series with 11 year moving average and 11 point Gaussian filter for uniform temperate region.

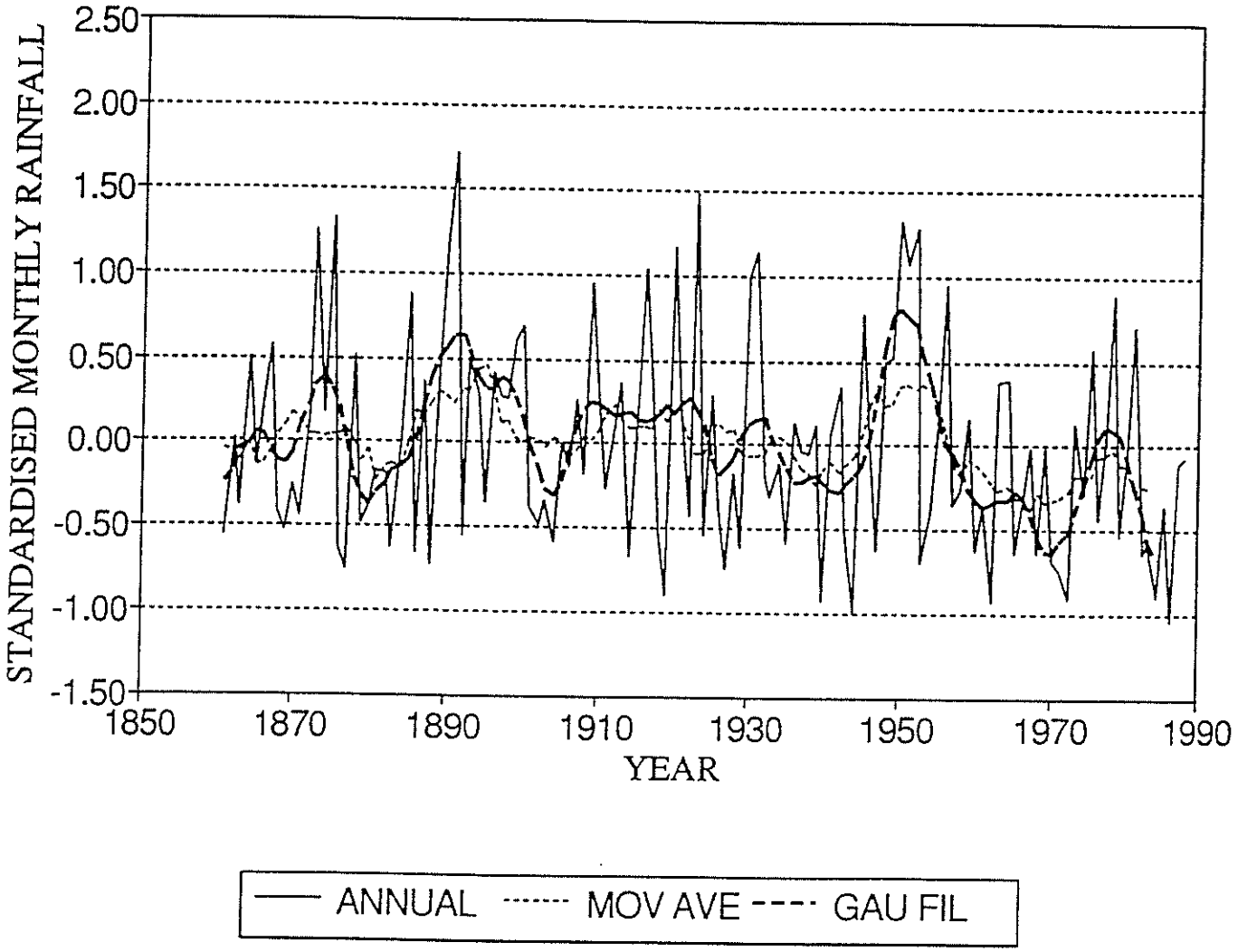


Fig B38 Plot of June rainfall time series with 11 year moving average and 11 point Gaussian filter for uniform temperate region.

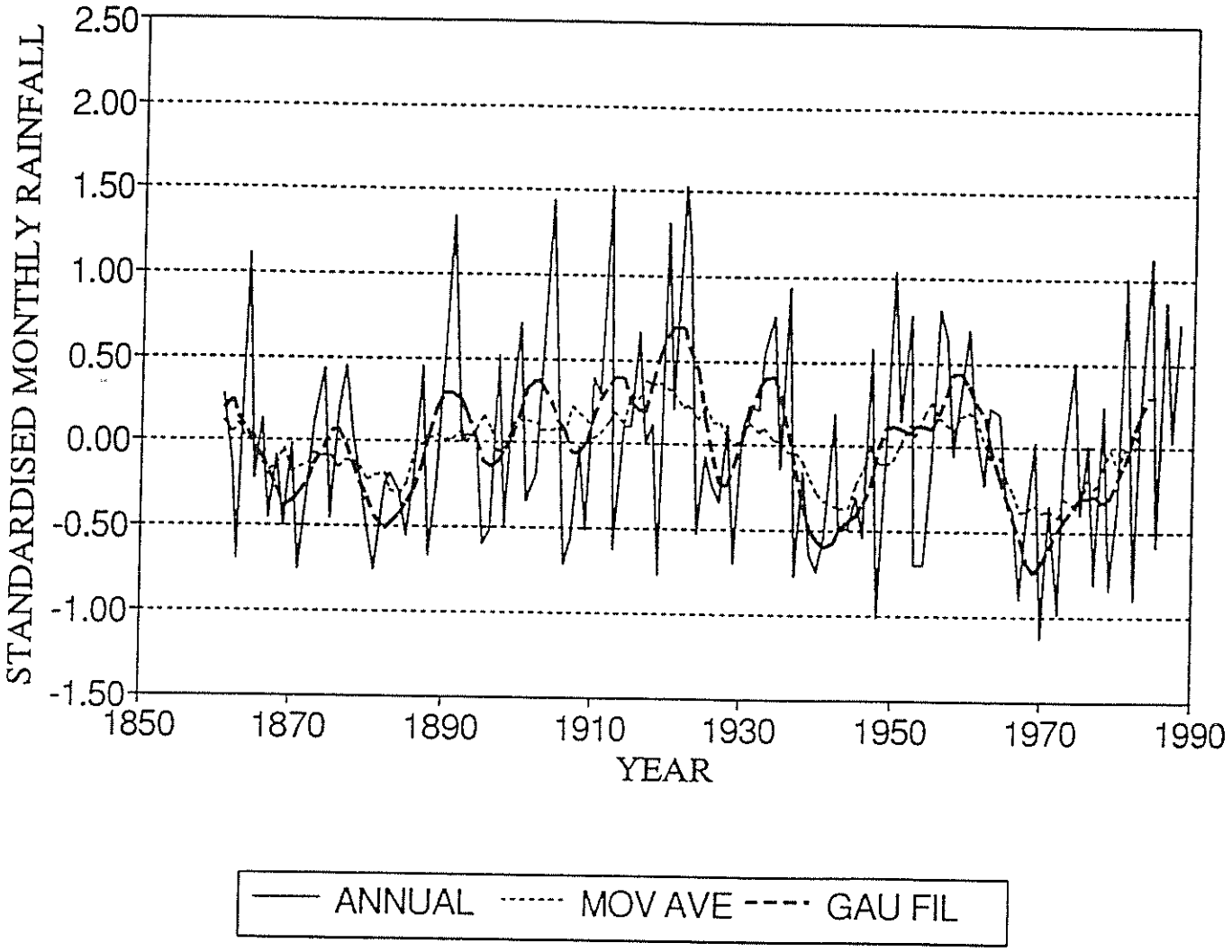


Fig B39 Plot of July rainfall time series with 11 year moving average and 11 point Gaussian filter for uniform temperate region.

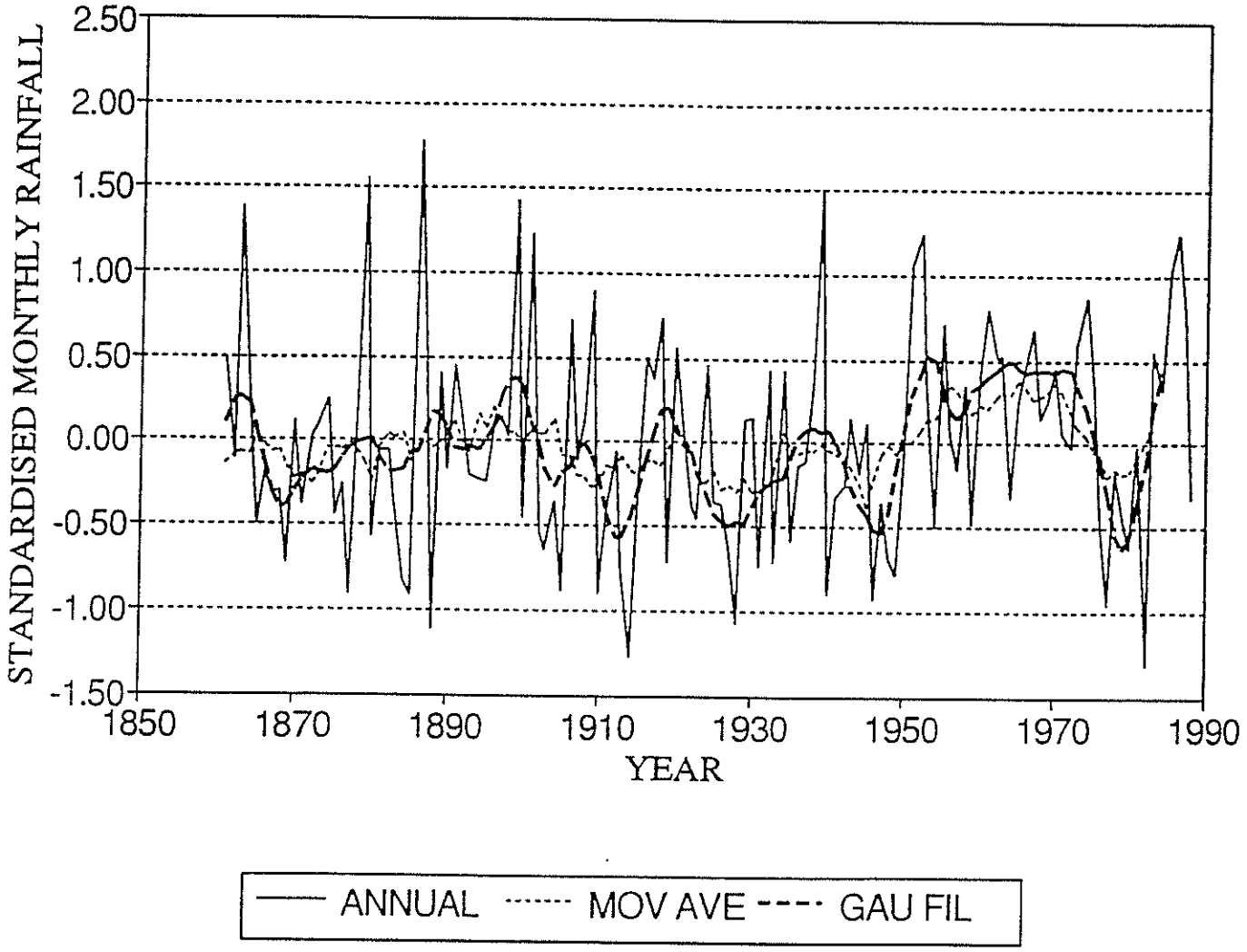


Fig B40 Plot of August rainfall time series with 11 year moving average and 11 point Gaussian filter for uniform temperate region.

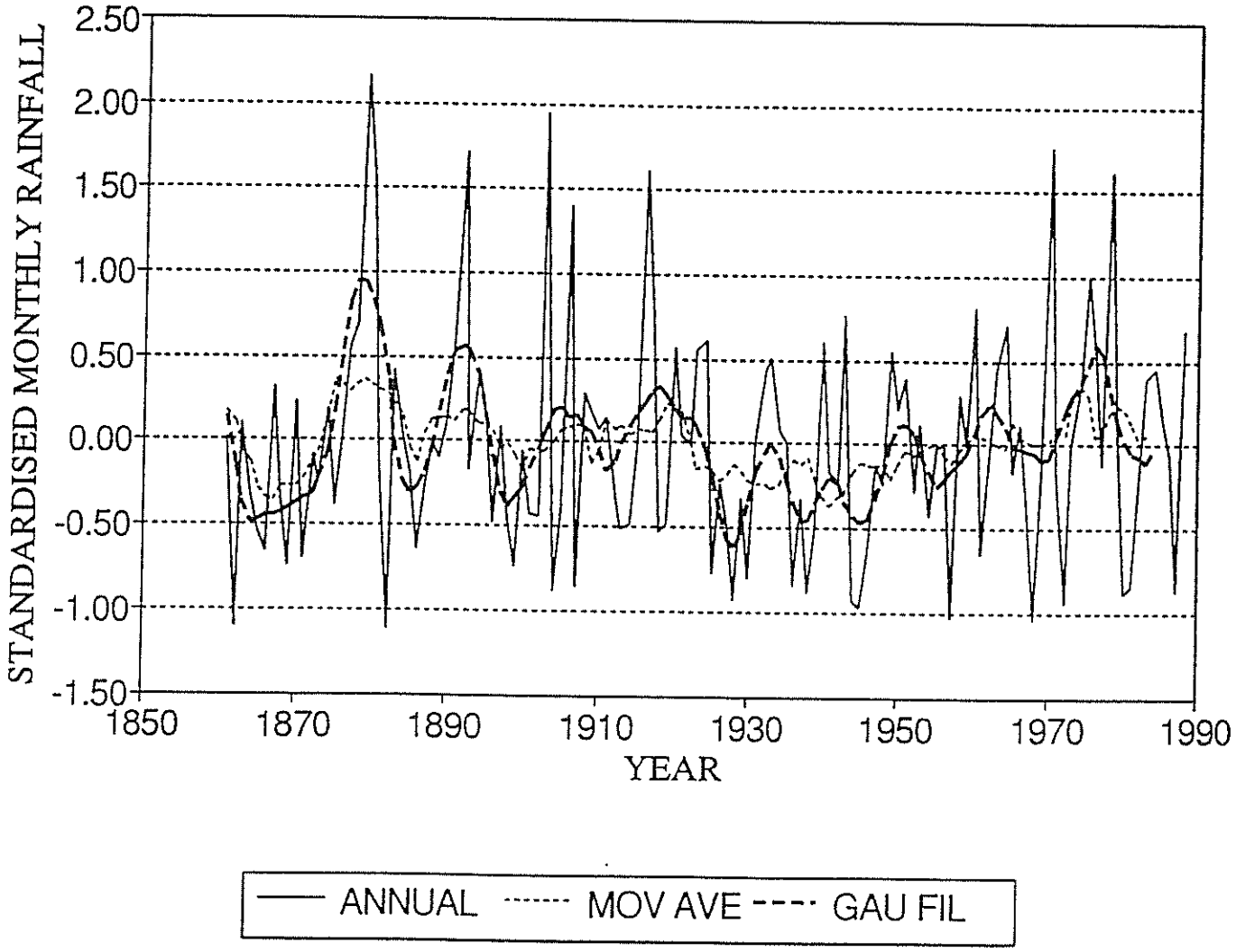


Fig B41 Plot of September rainfall time series with 11 year moving average and 11 point Gaussian filter for uniform temperate region.

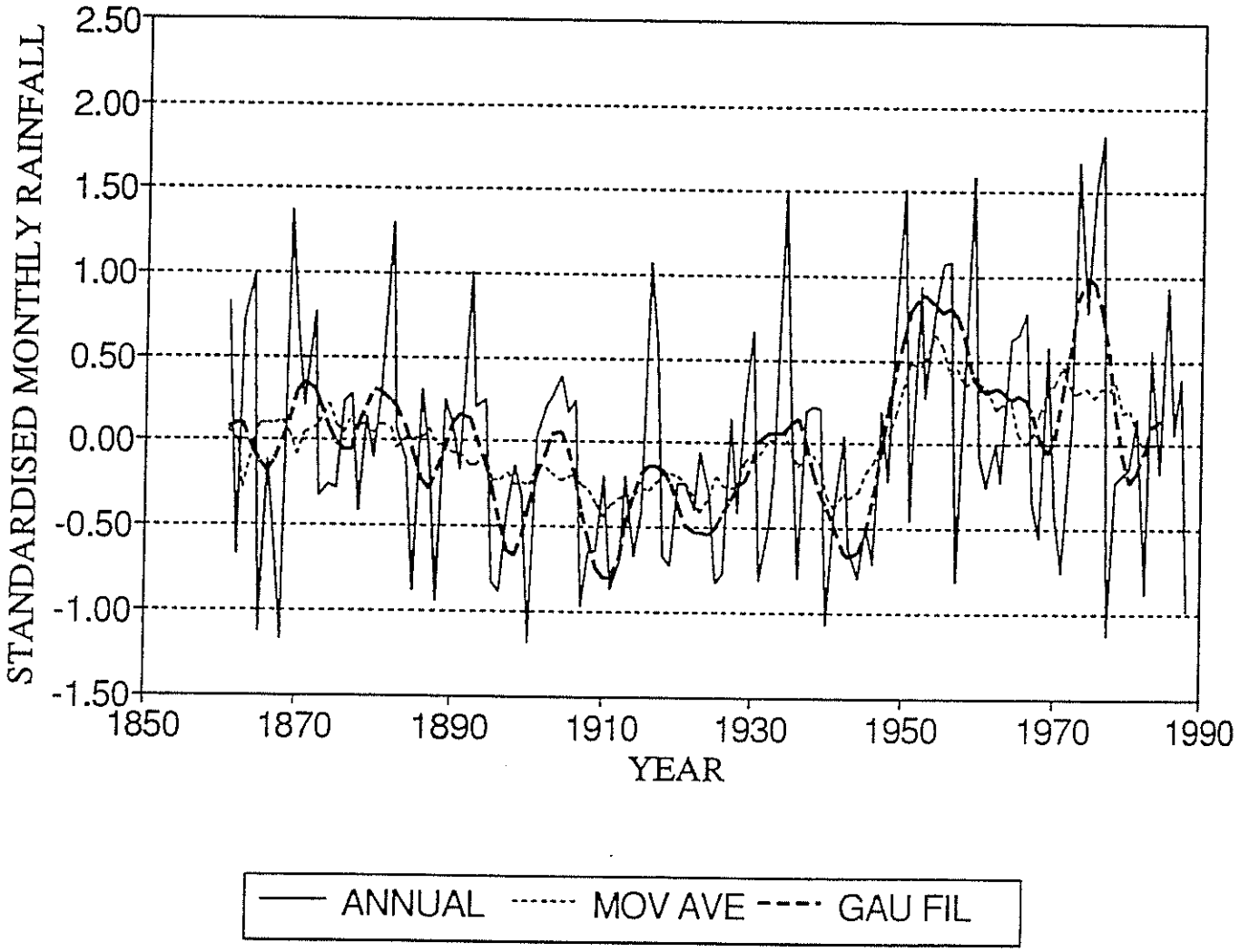


Fig B42 Plot of October rainfall time series with 11 year moving average and 11 point Gaussian filter for uniform temperate region.

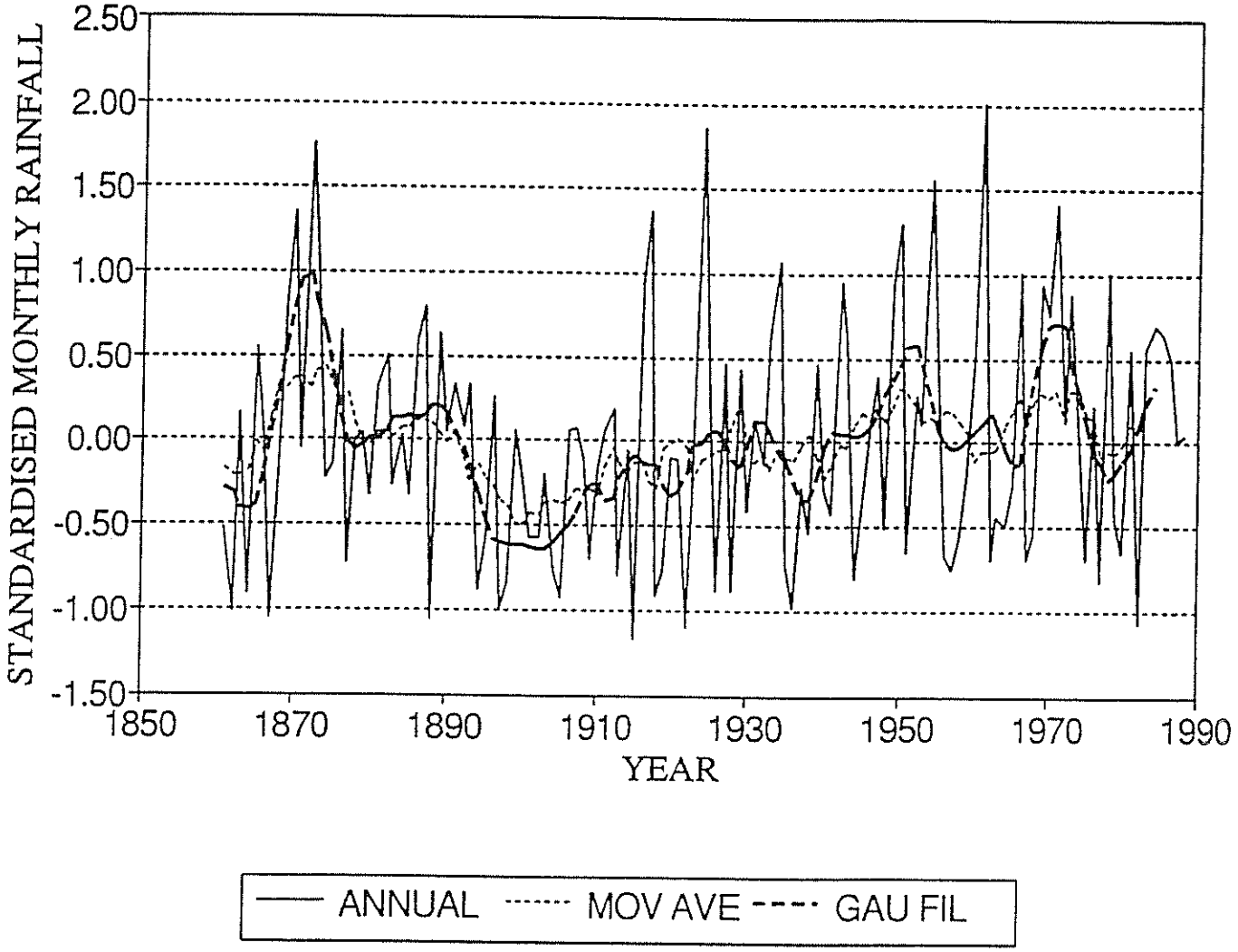


Fig B43 Plot of November rainfall time series with 11 year moving average and 11 point Gaussian filter for uniform temperate region.

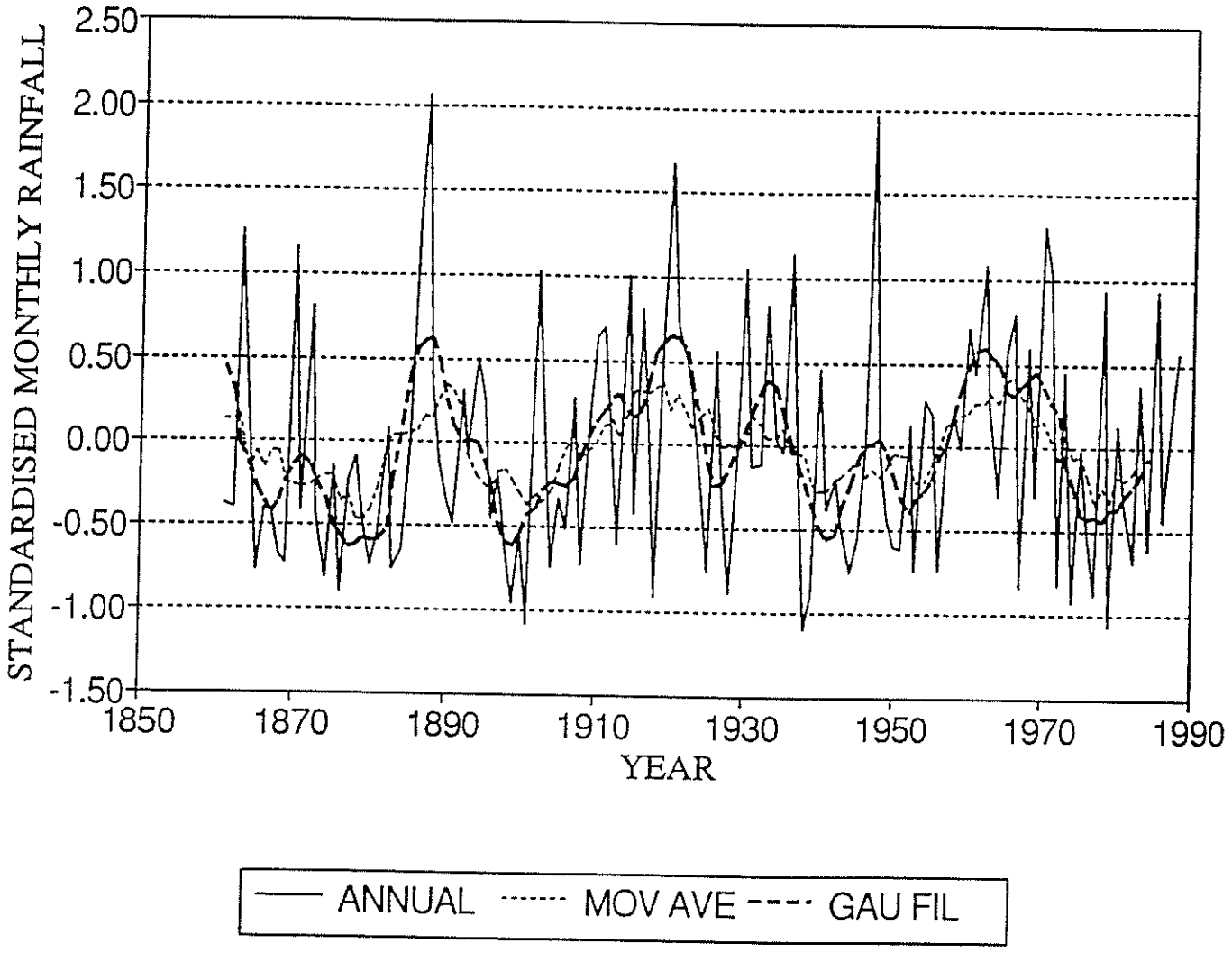


Fig B44 Plot of December rainfall time series with 11 year moving average and 11 point Gaussian filter for uniform temperate region.

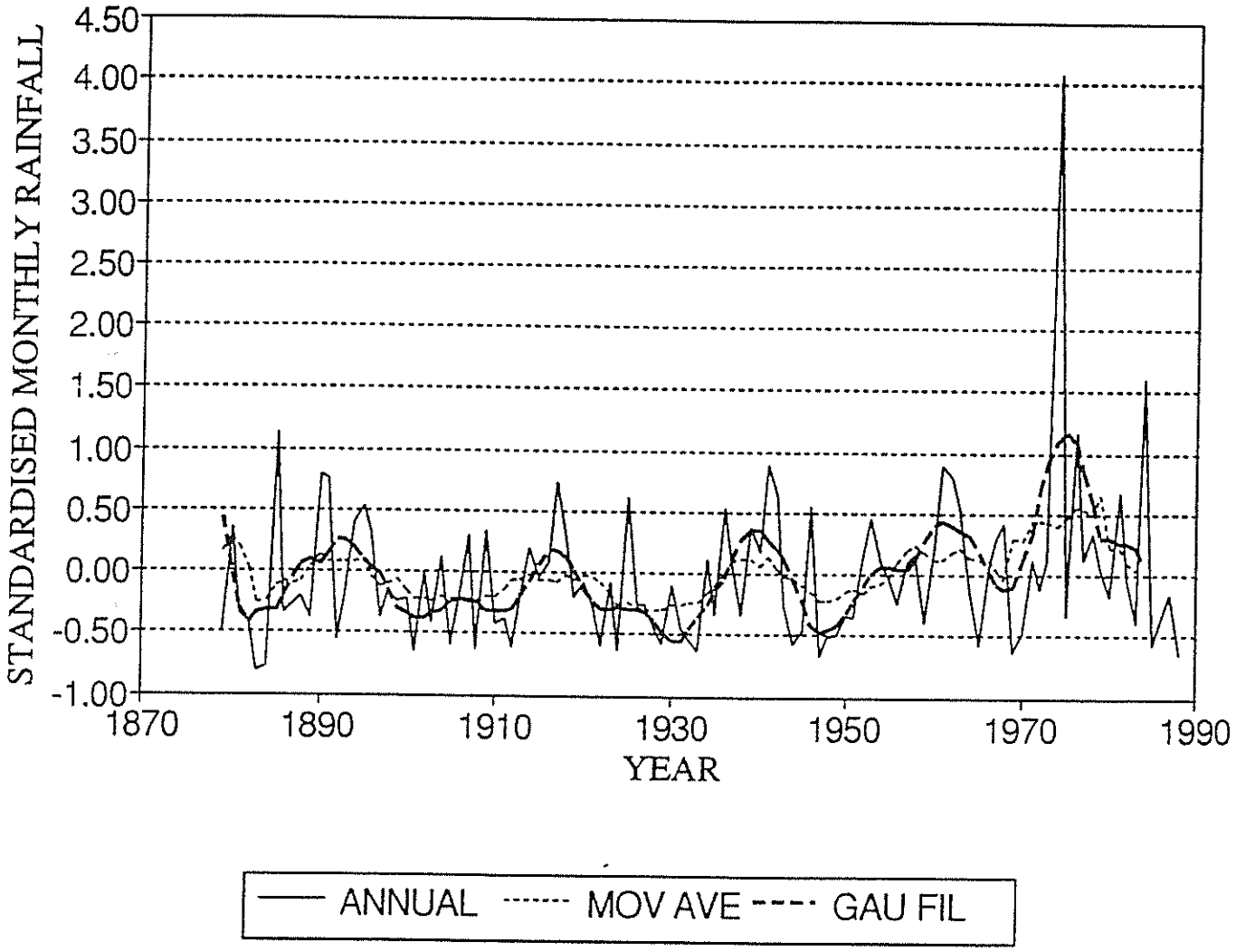


Fig B45 Plot of January rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

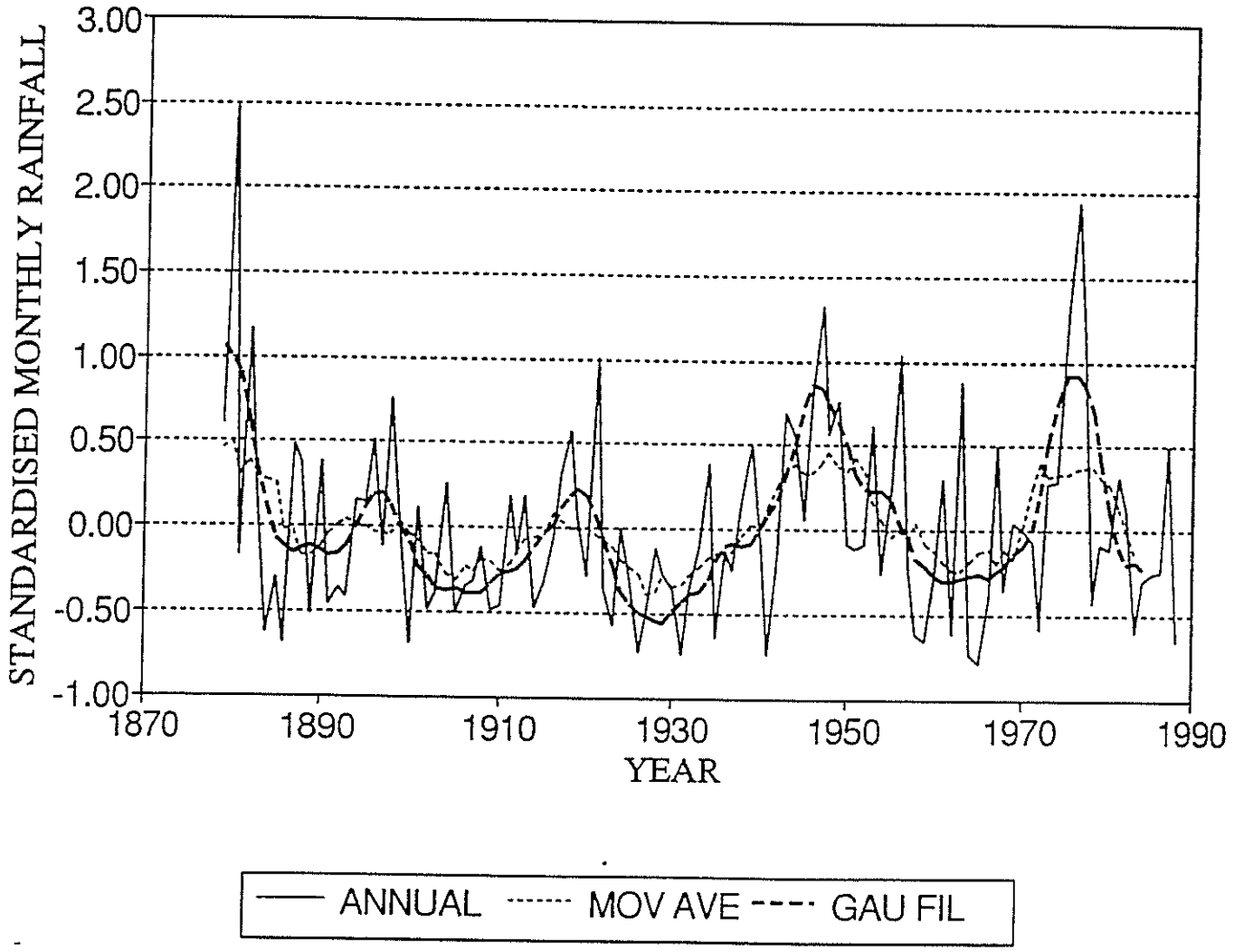


Fig B46 Plot of February rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

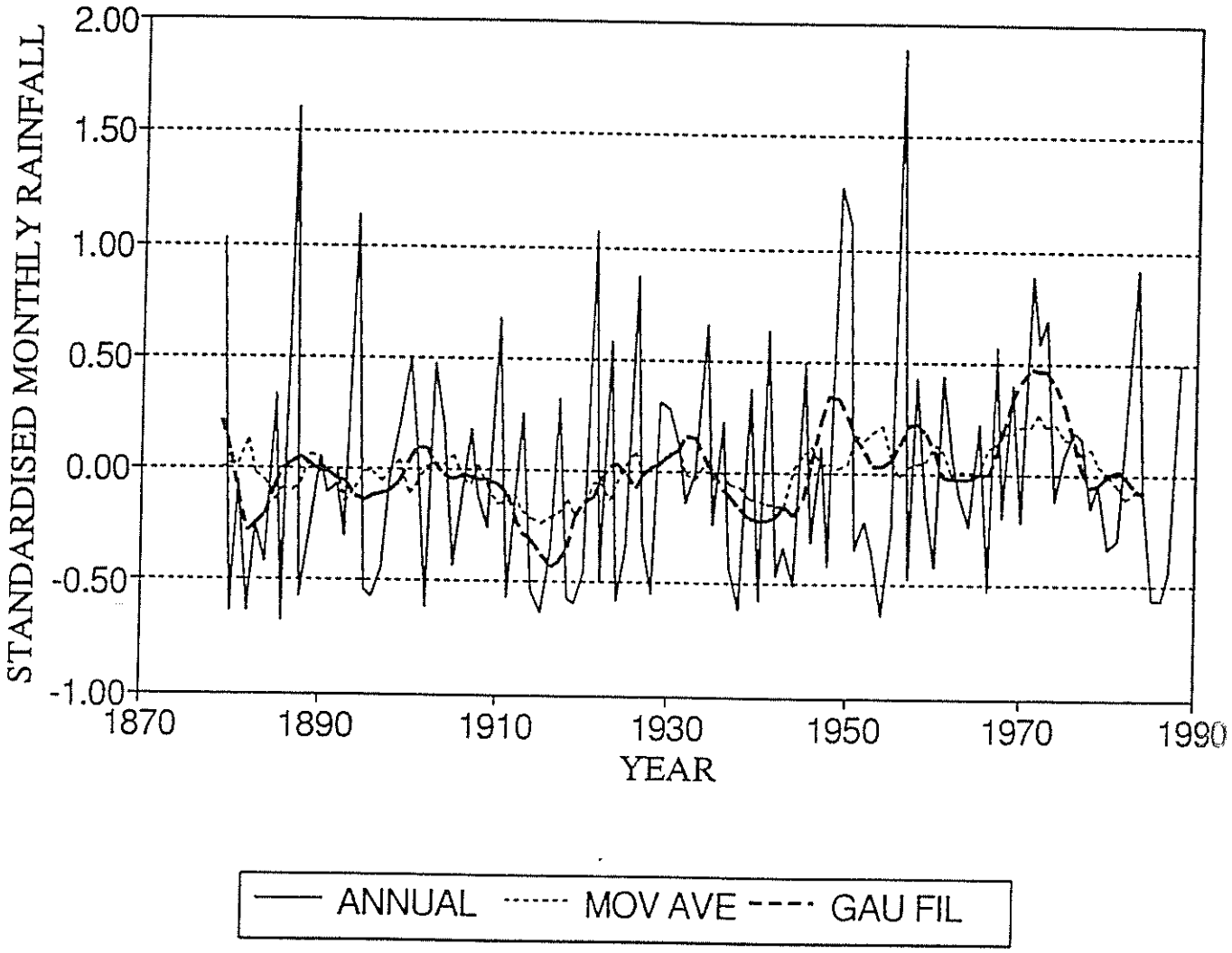


Fig B47 Plot of March rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

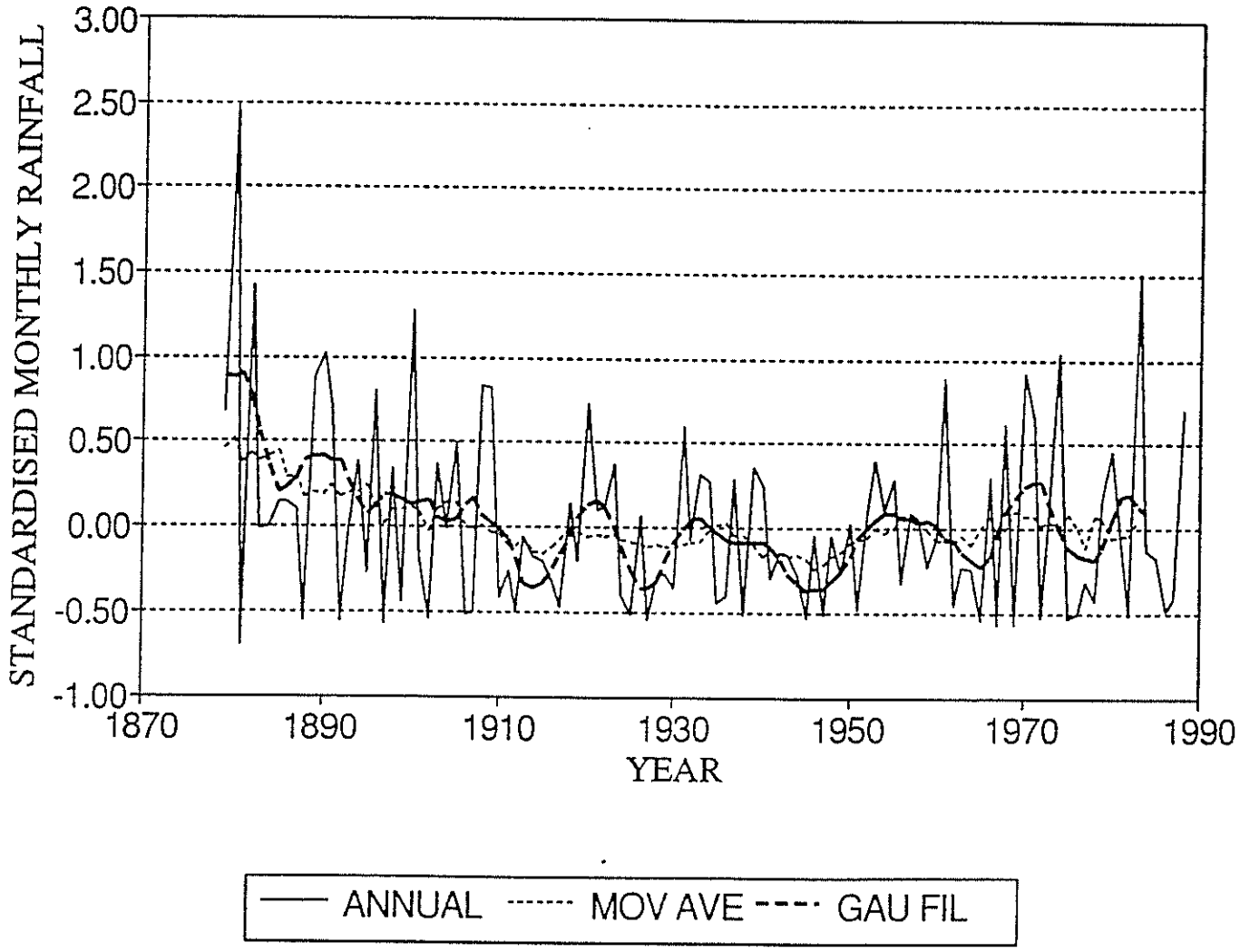


Fig B48 Plot of April rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

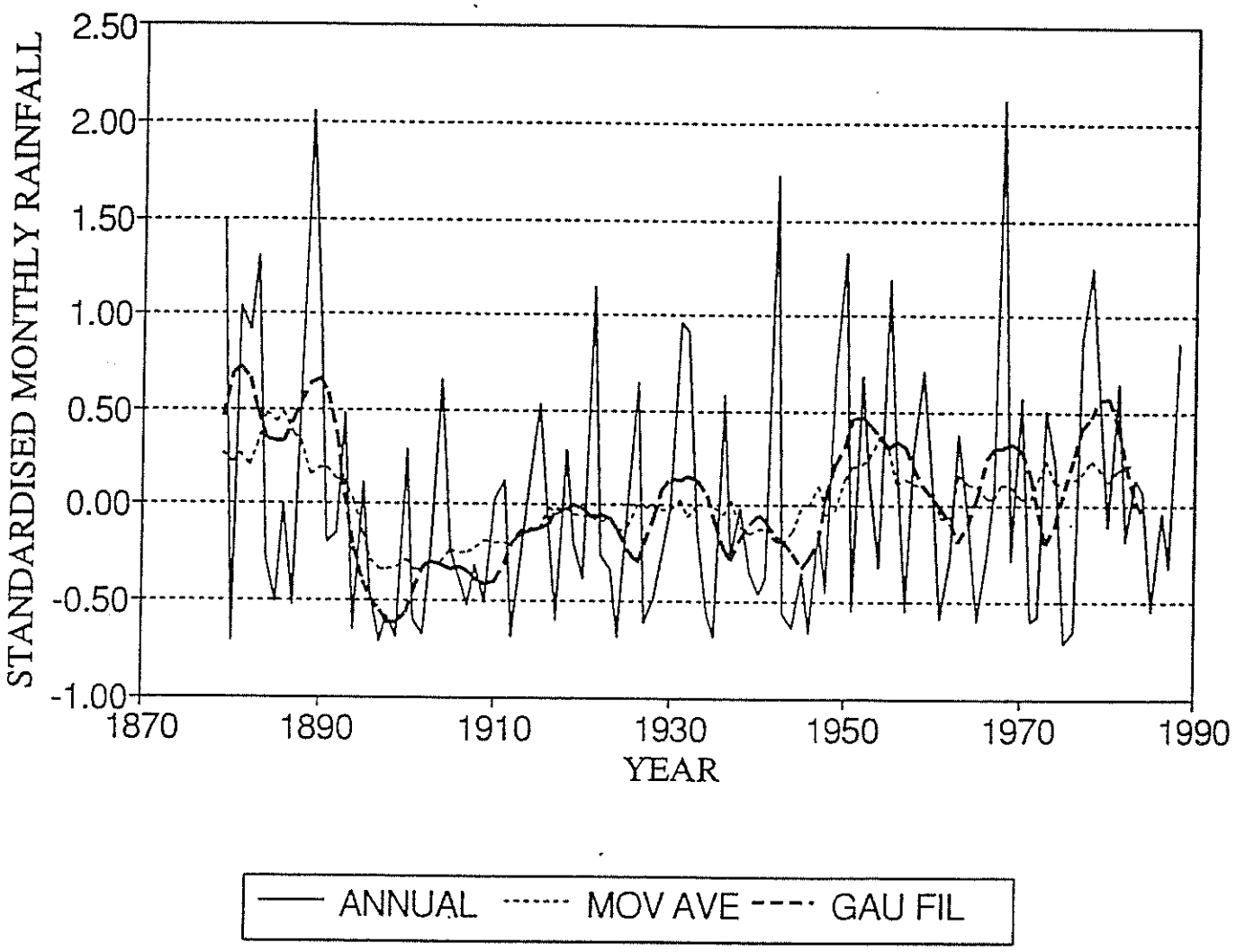


Fig B49 Plot of May rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

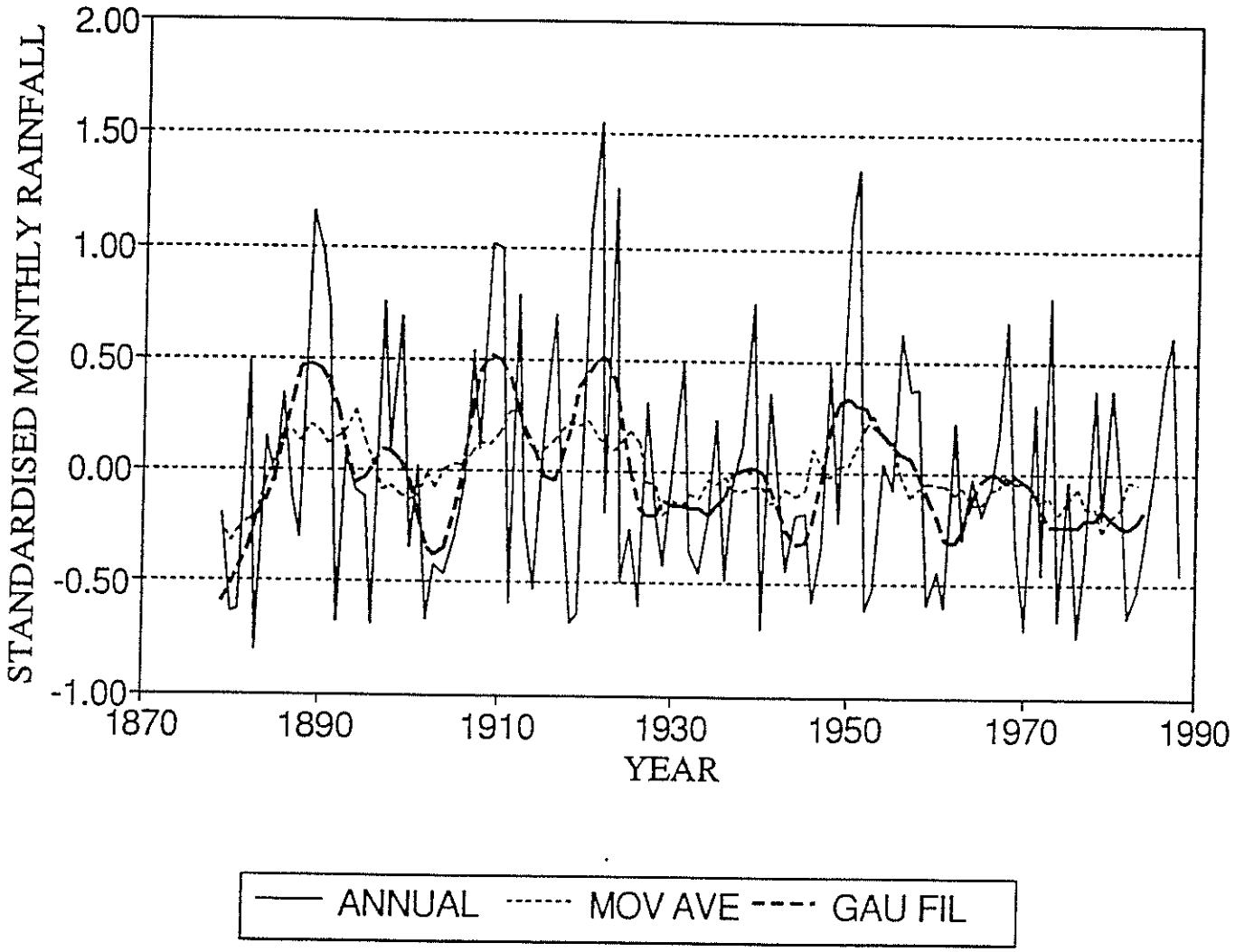


Fig B50 Plot of June rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

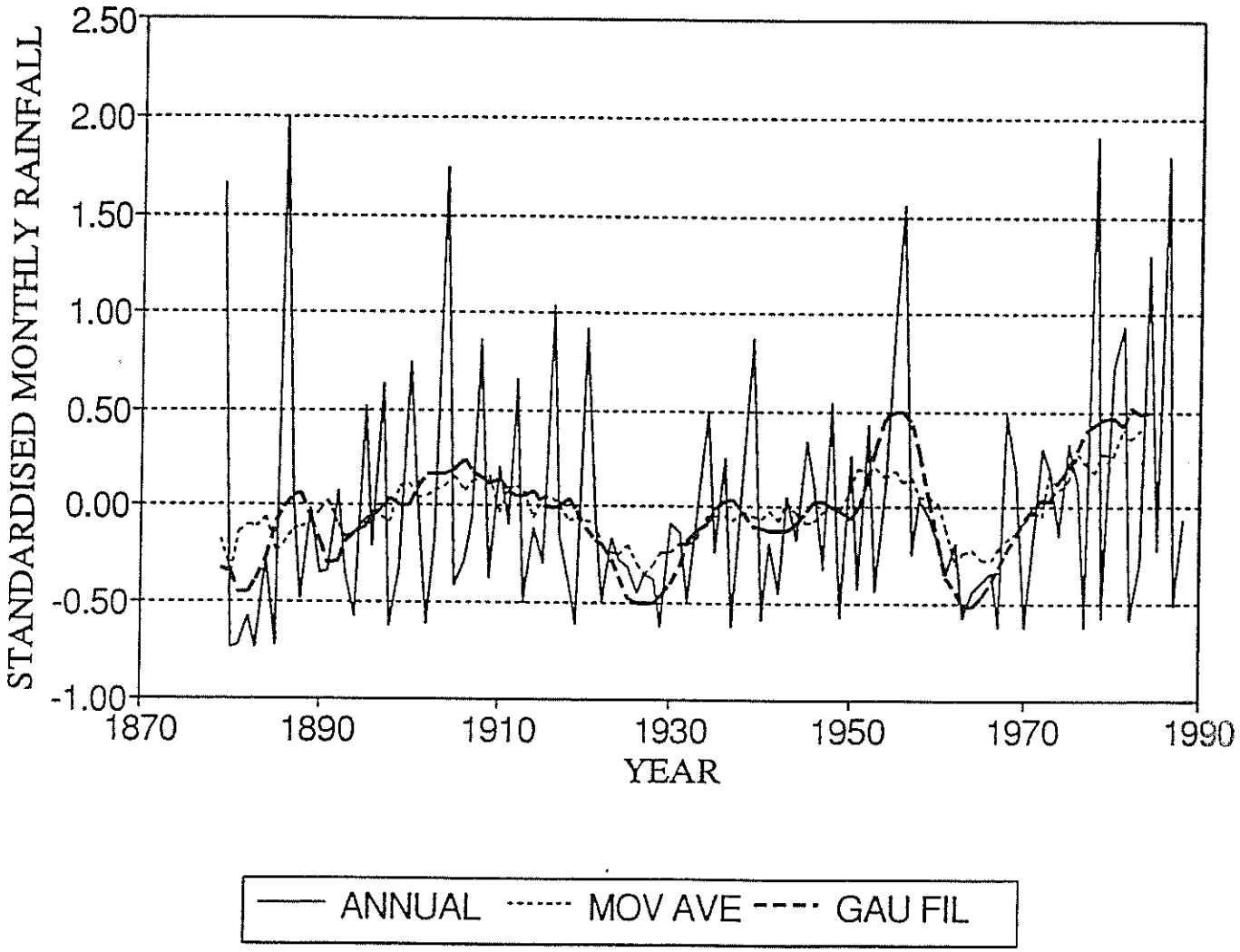


Fig B51 Plot of July rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

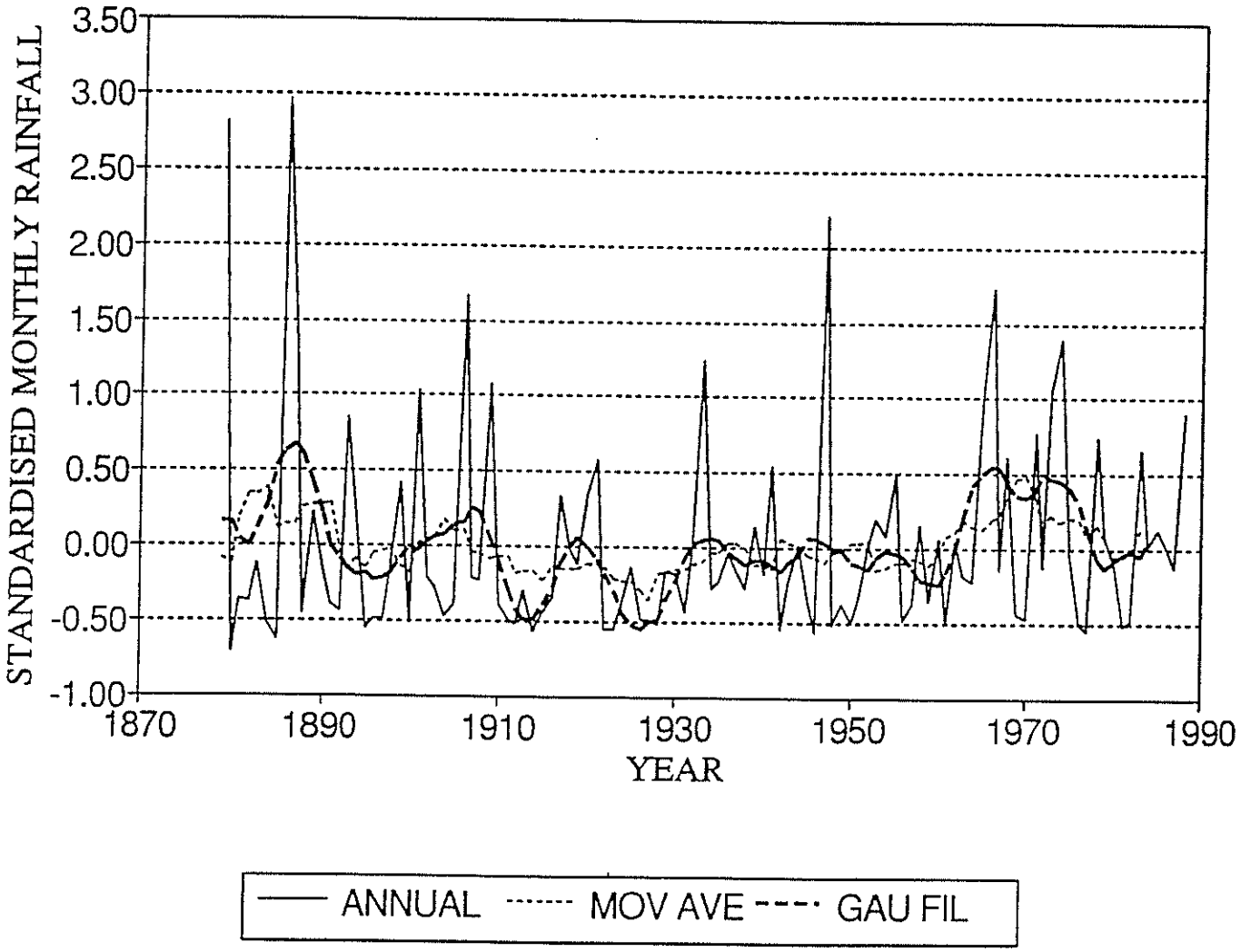


Fig B52 Plot of August rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

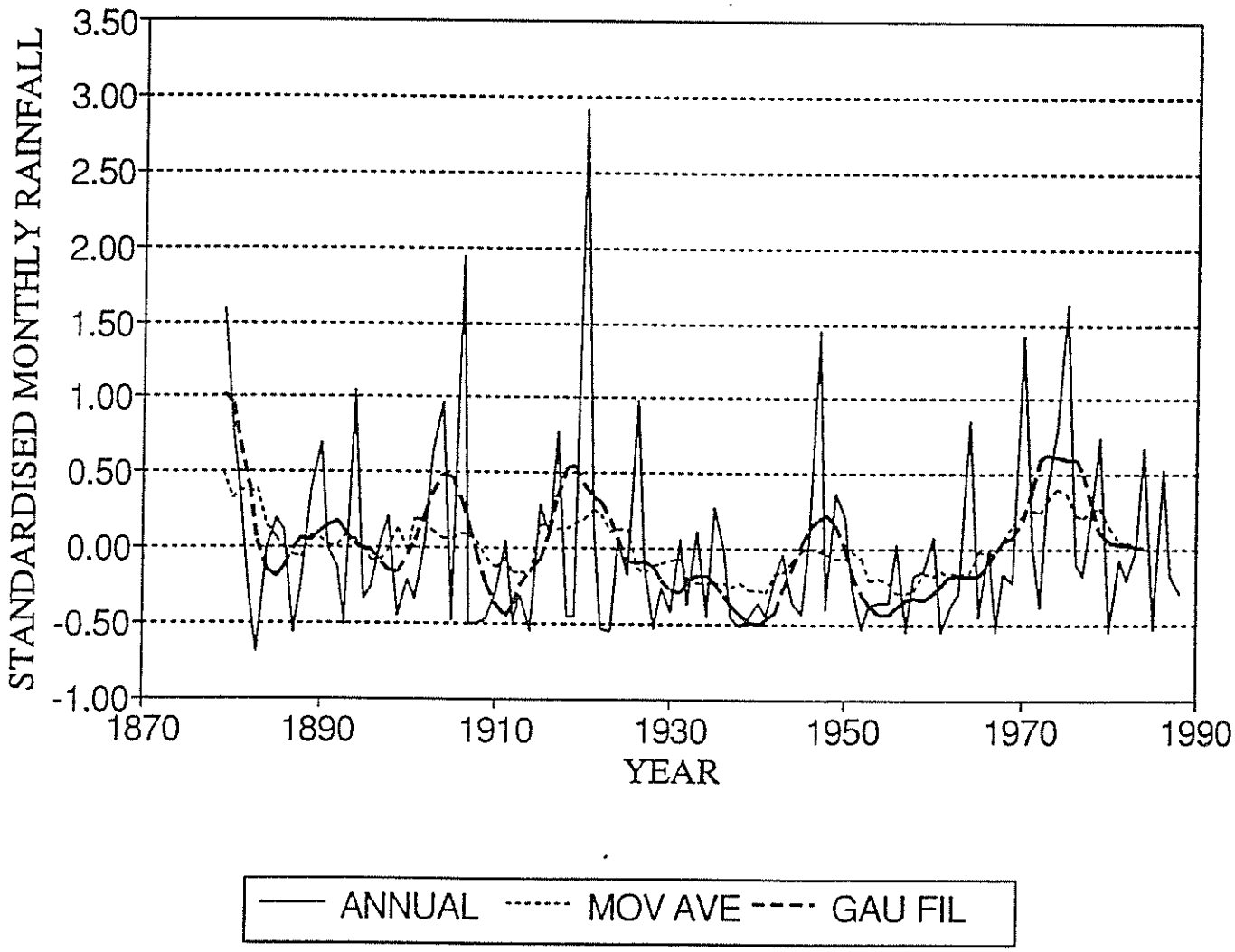


Fig B53 Plot of September rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

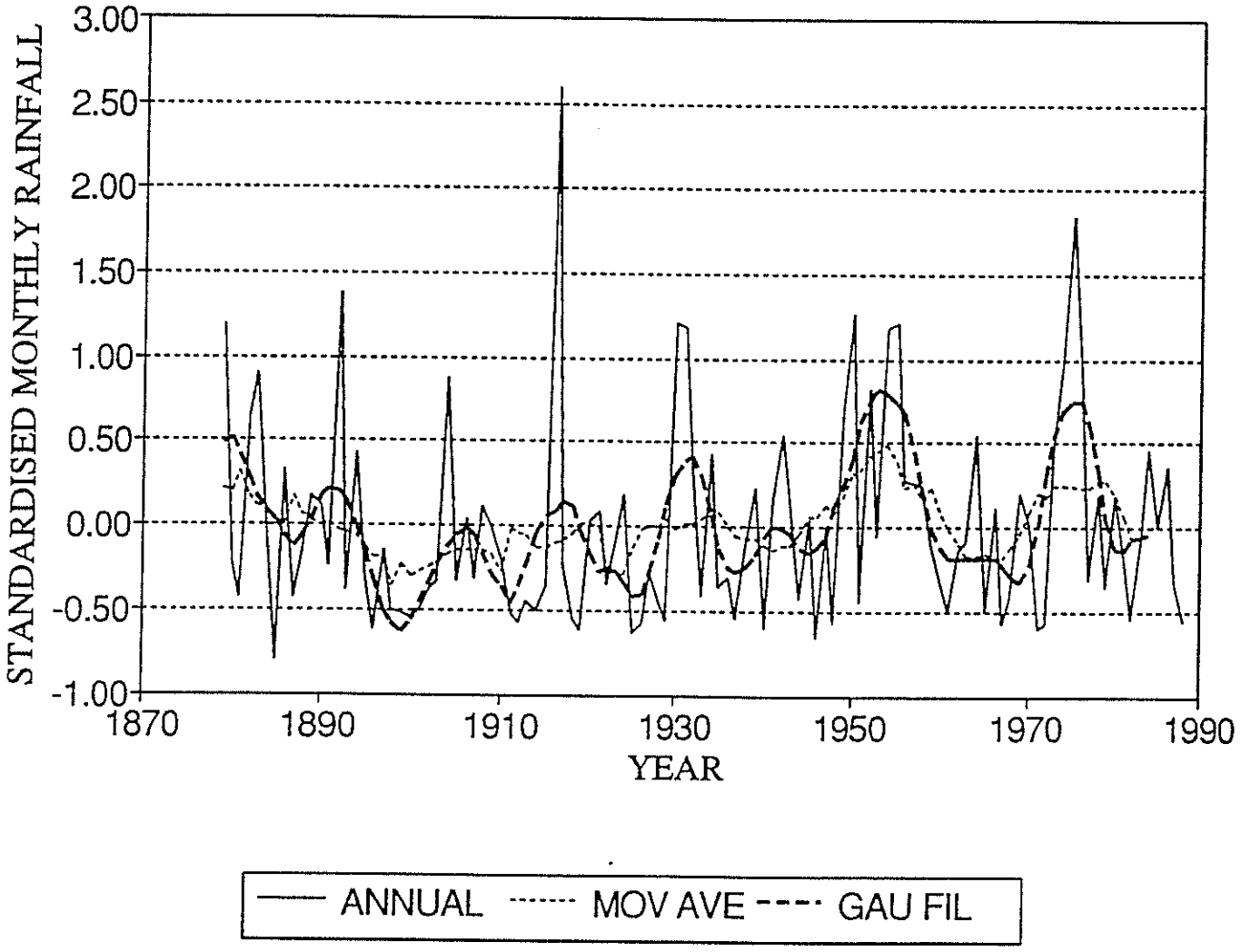


Fig B54 Plot of October rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

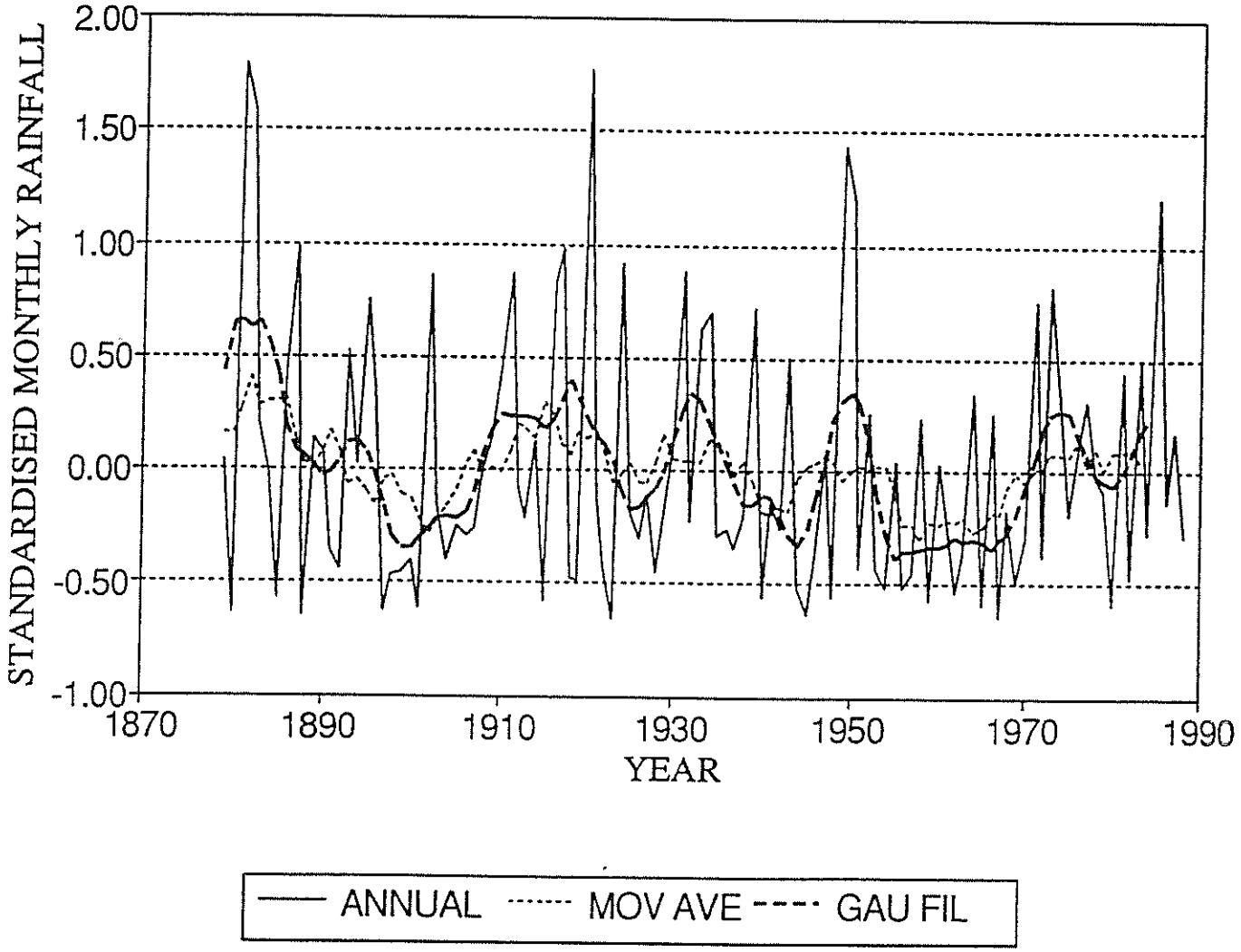


Fig B55 Plot of November rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

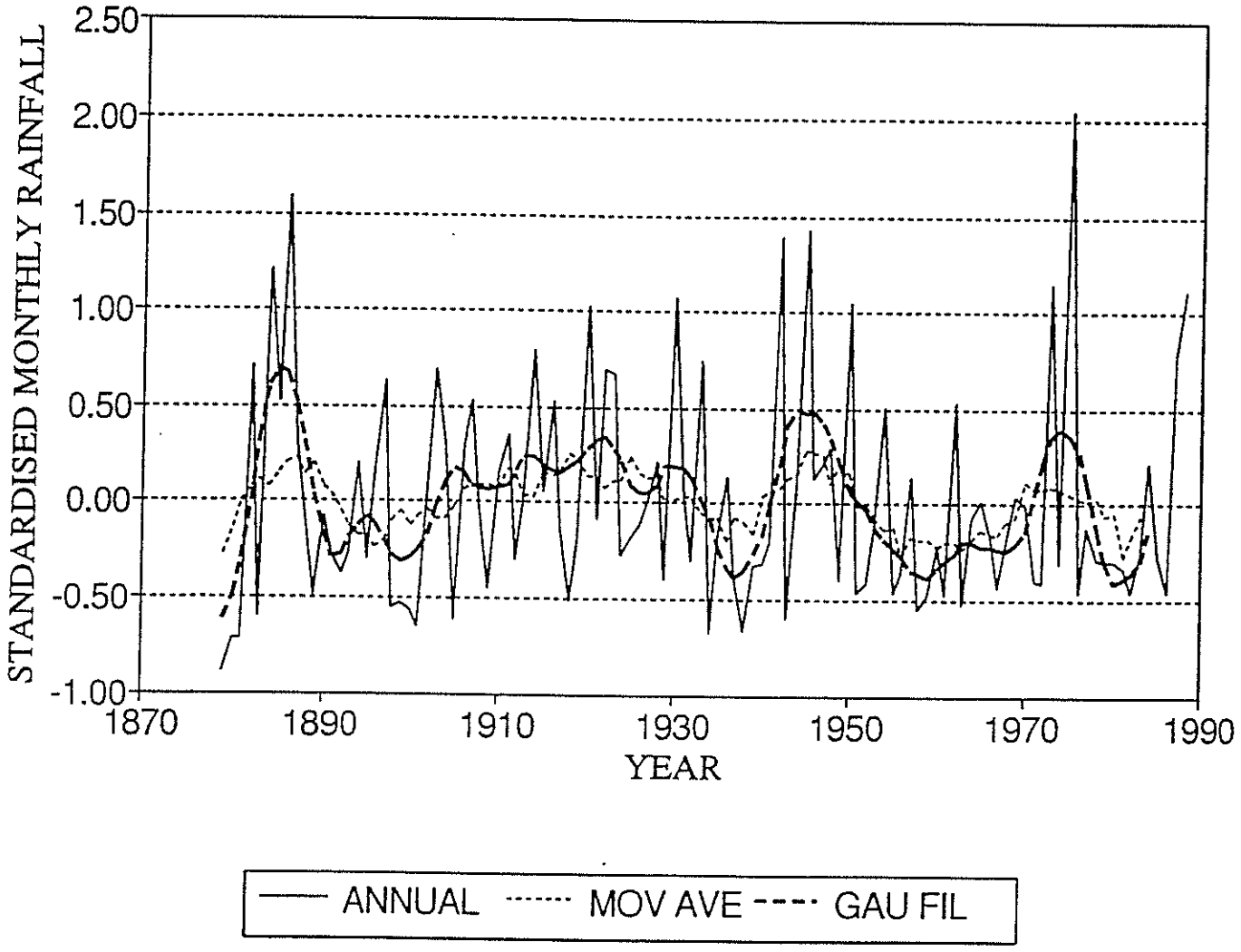


Fig B56 Plot of December rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

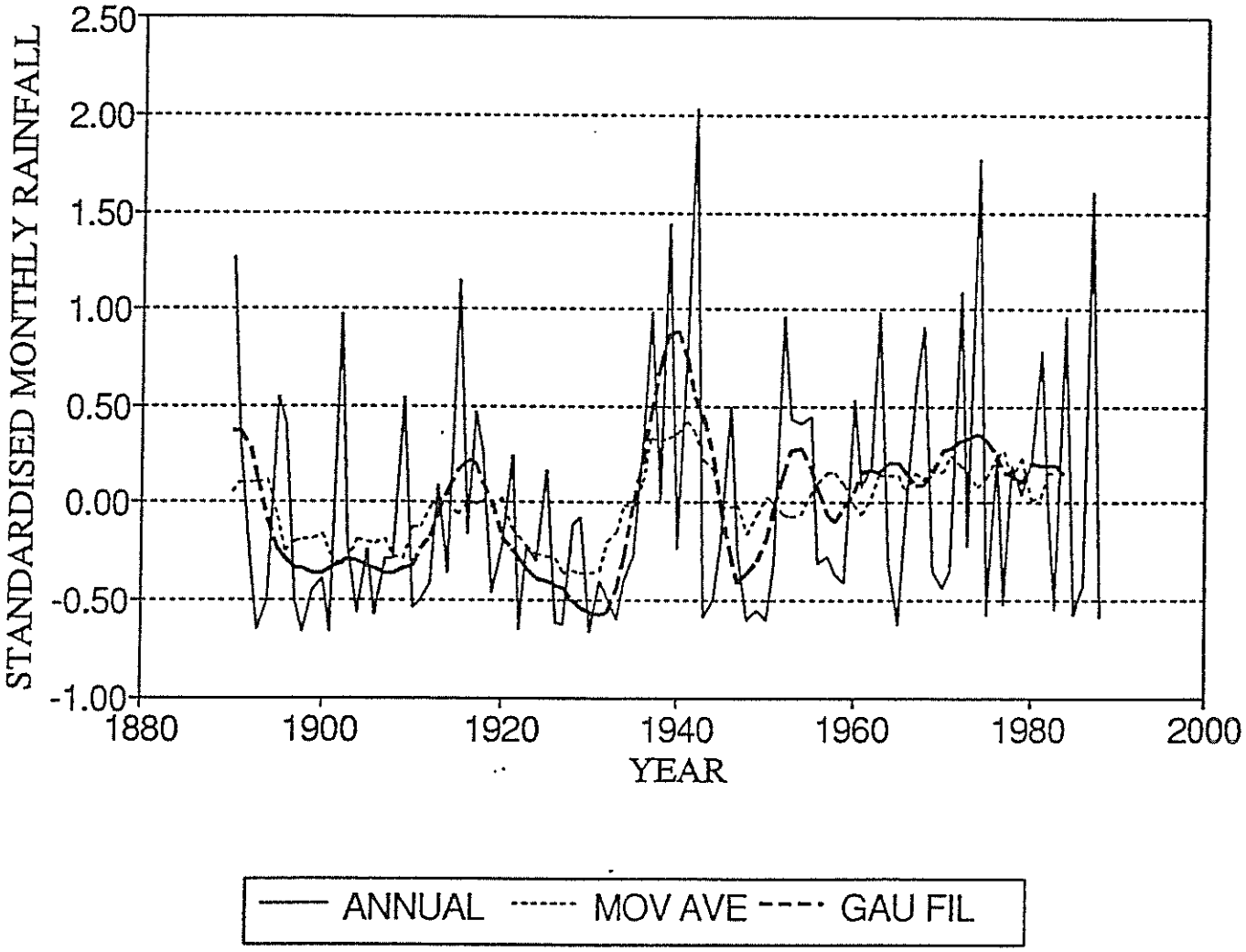


Fig B57 Plot of January rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

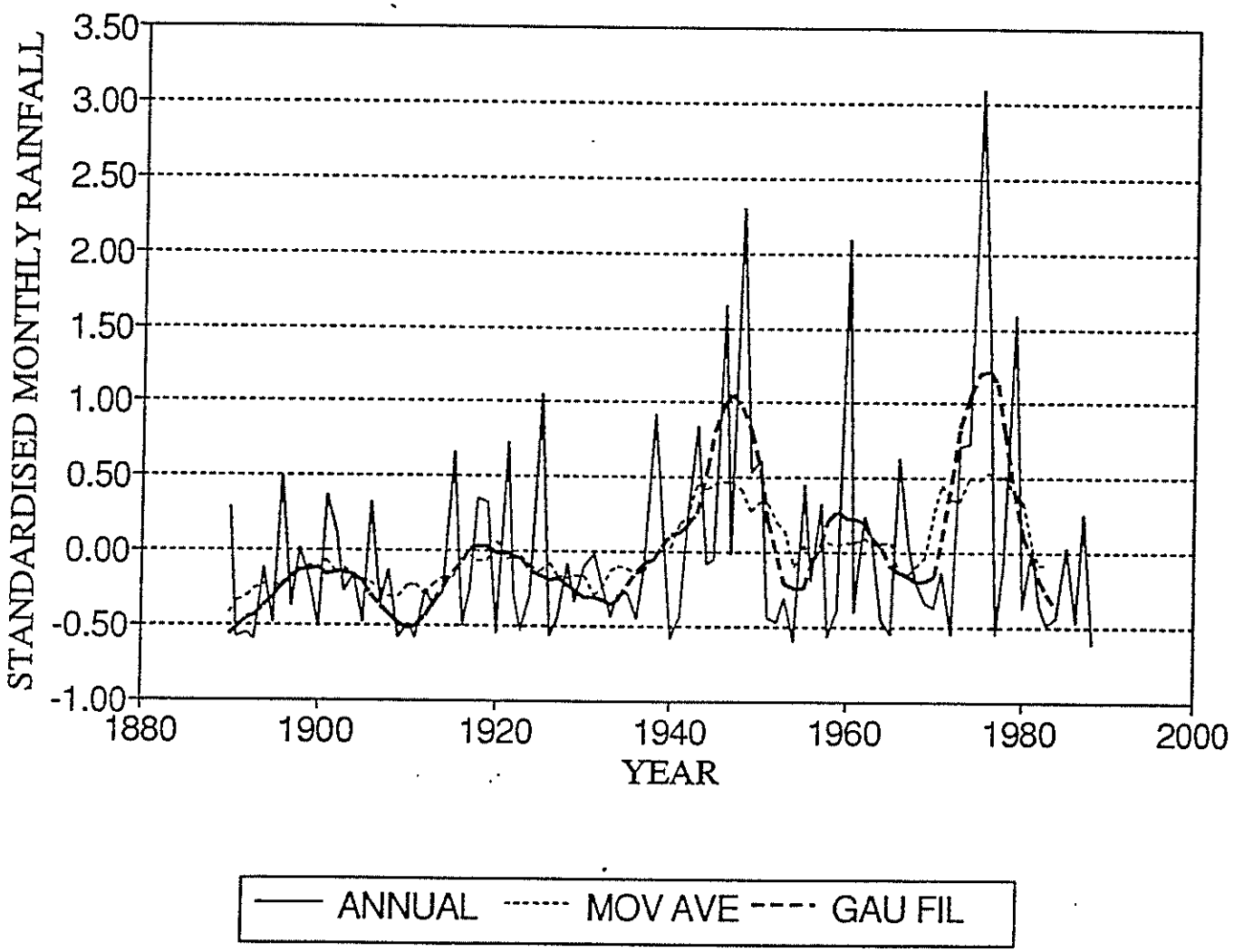


Fig B58 Plot of February rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

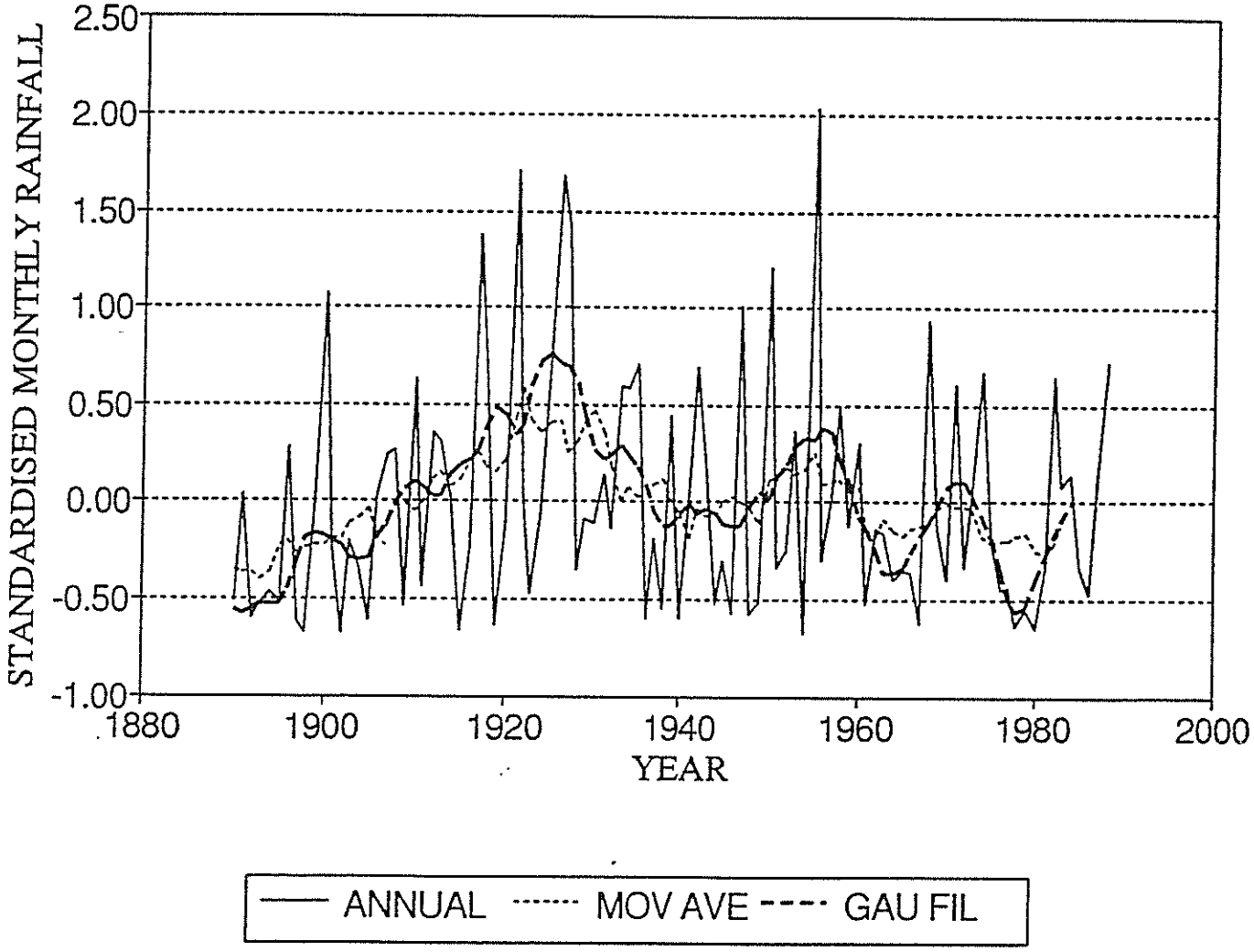


Fig B59 Plot of March rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

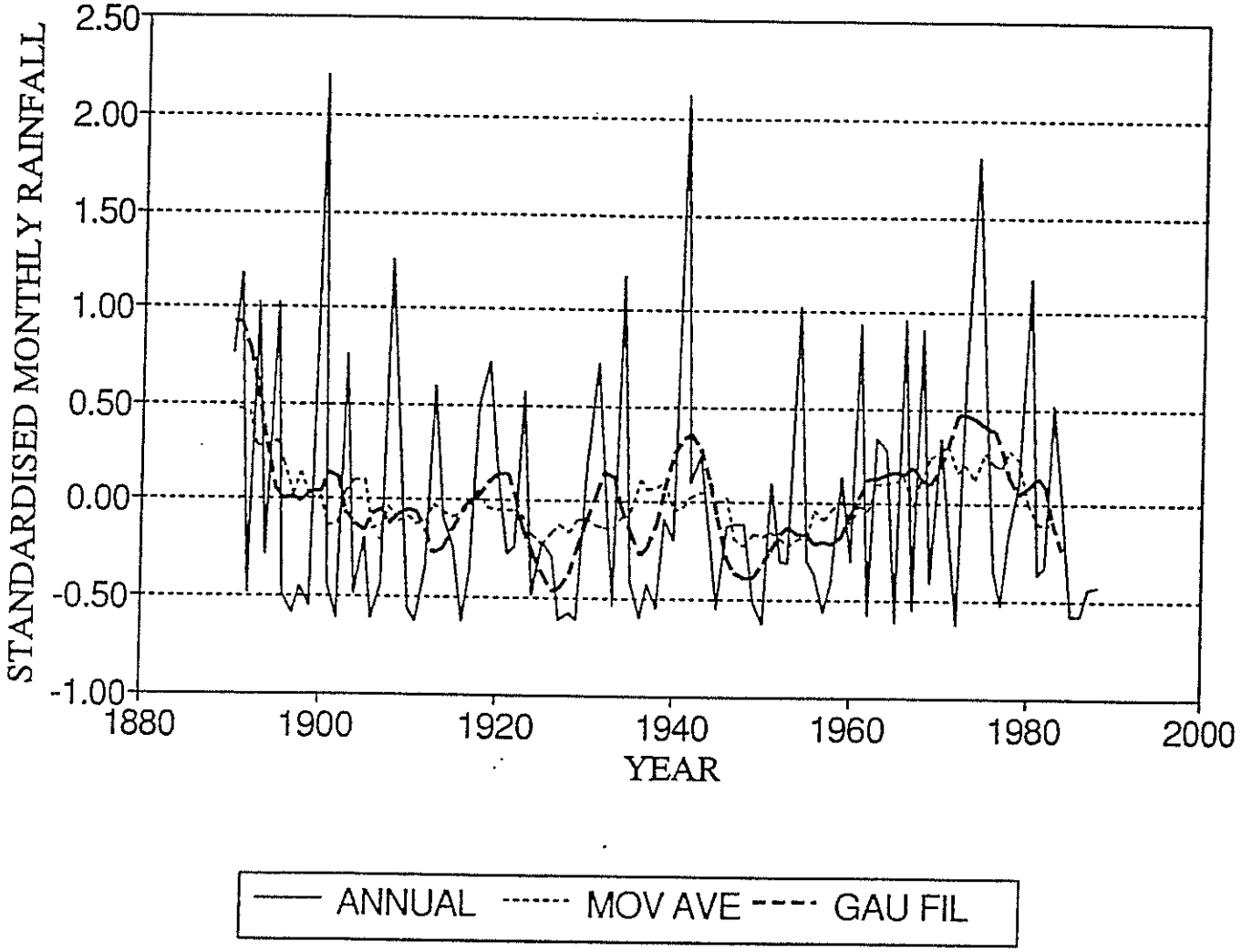


Fig B60 Plot of April rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

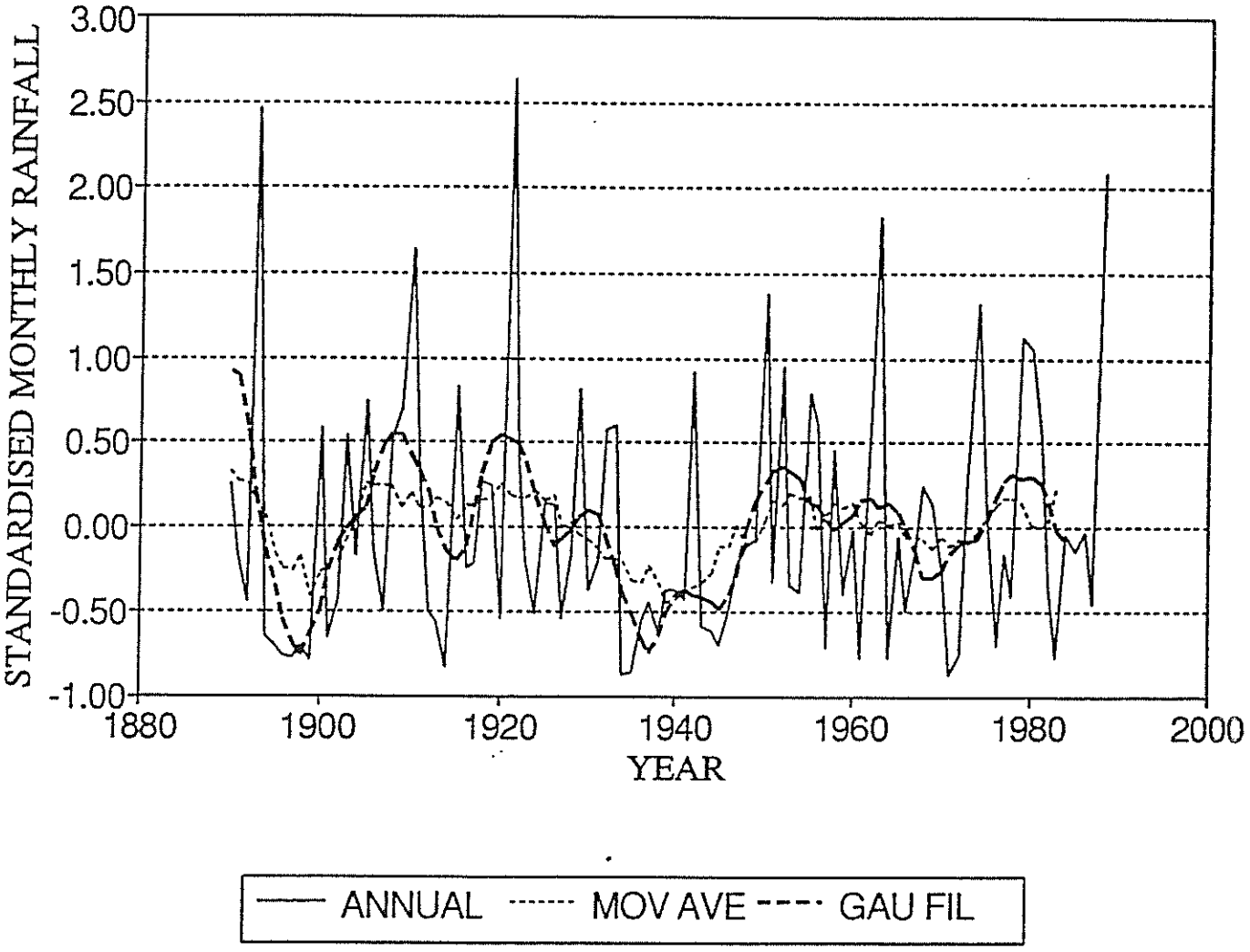


Fig B61 Plot of May rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

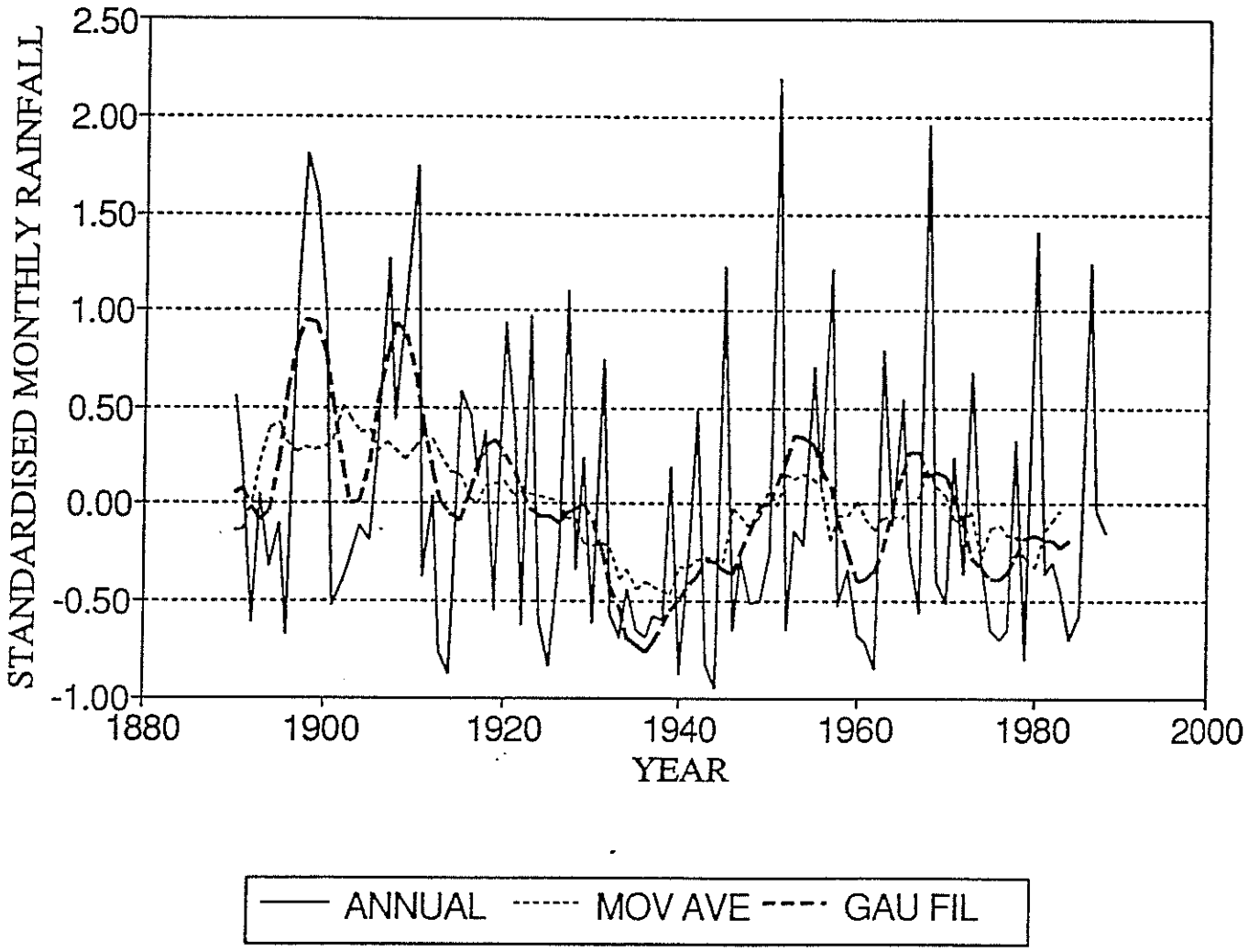


Fig B62 Plot of June rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

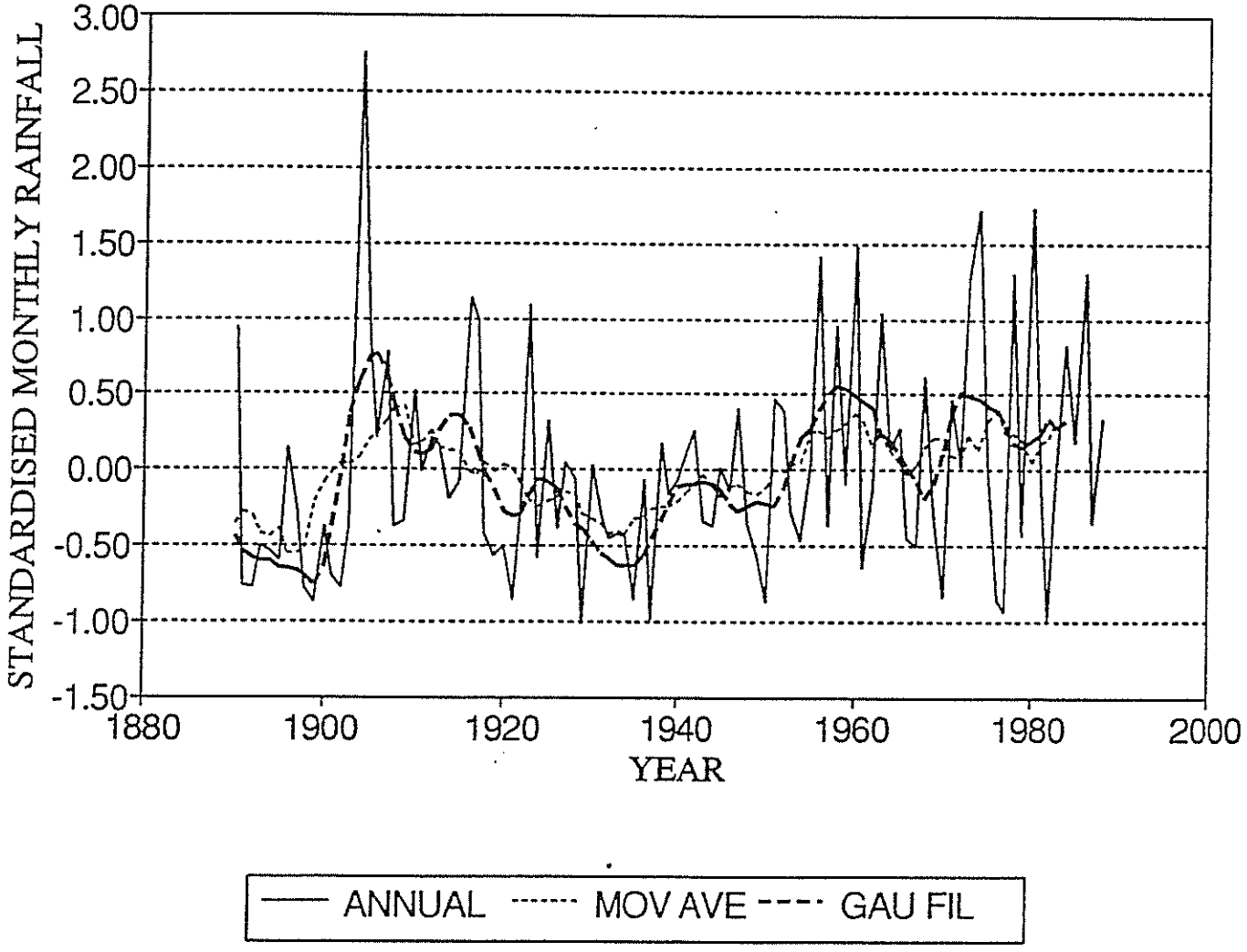


Fig B63 Plot of July rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

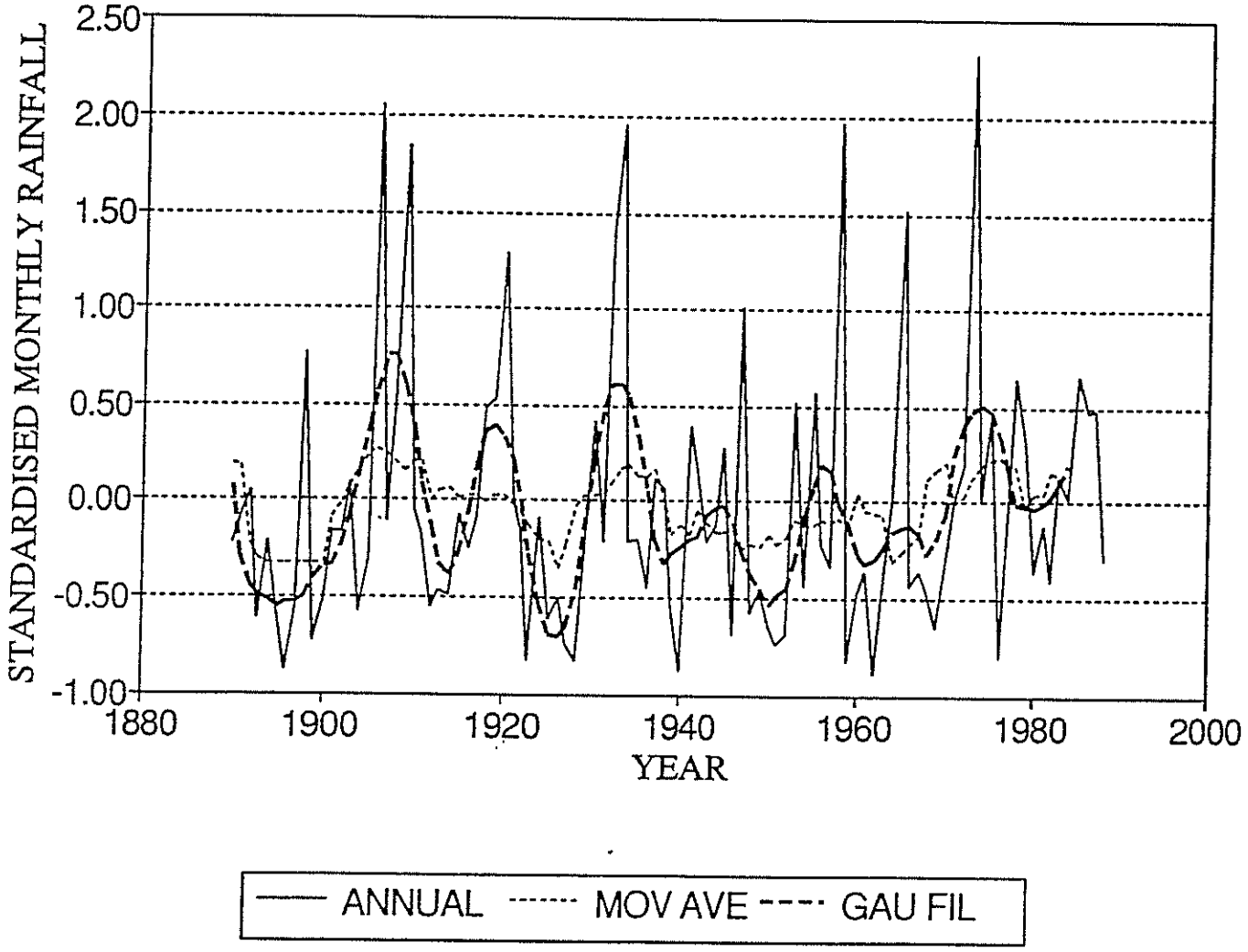


Fig B64 Plot of August rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

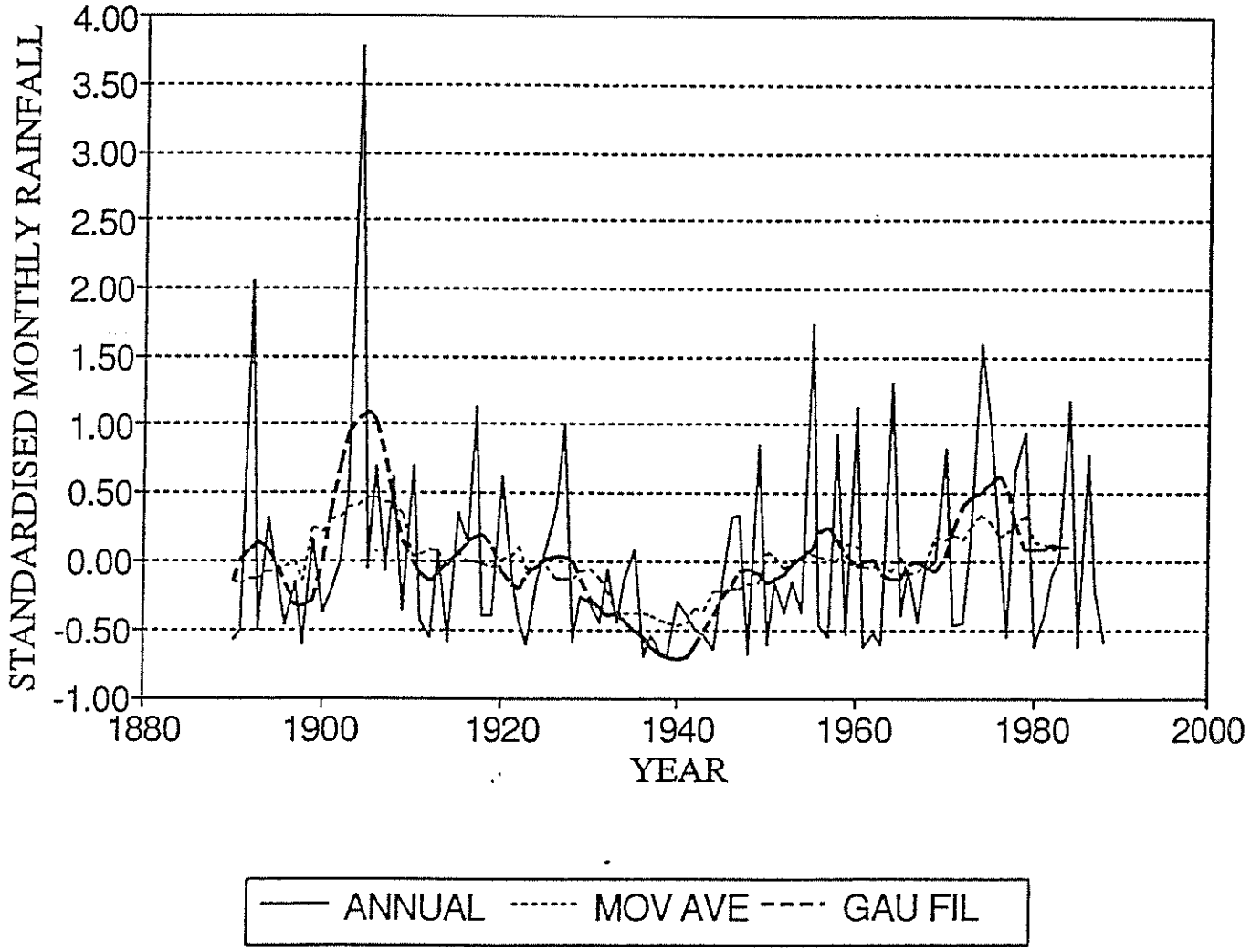


Fig B65 Plot of September rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

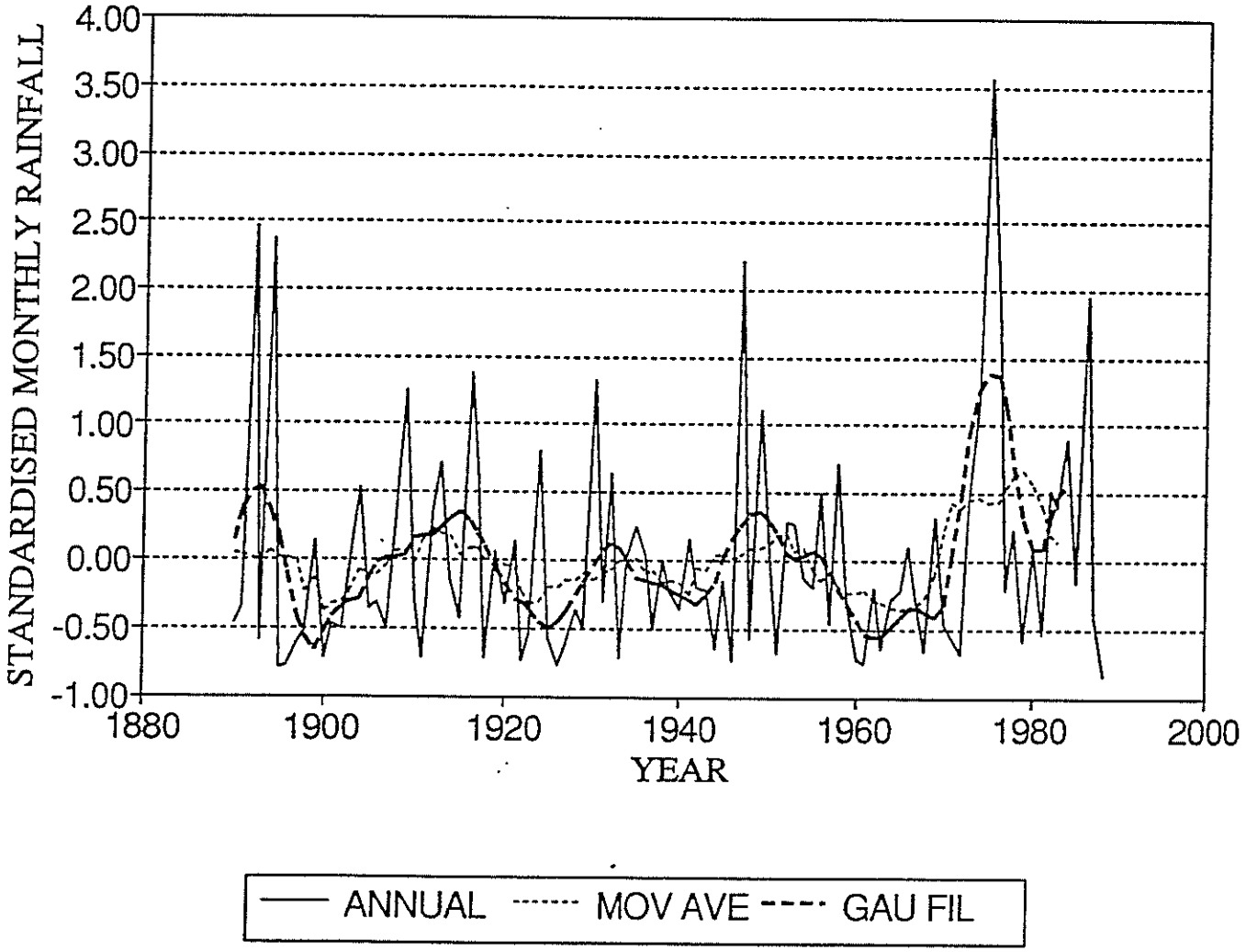


Fig B66 Plot of October rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

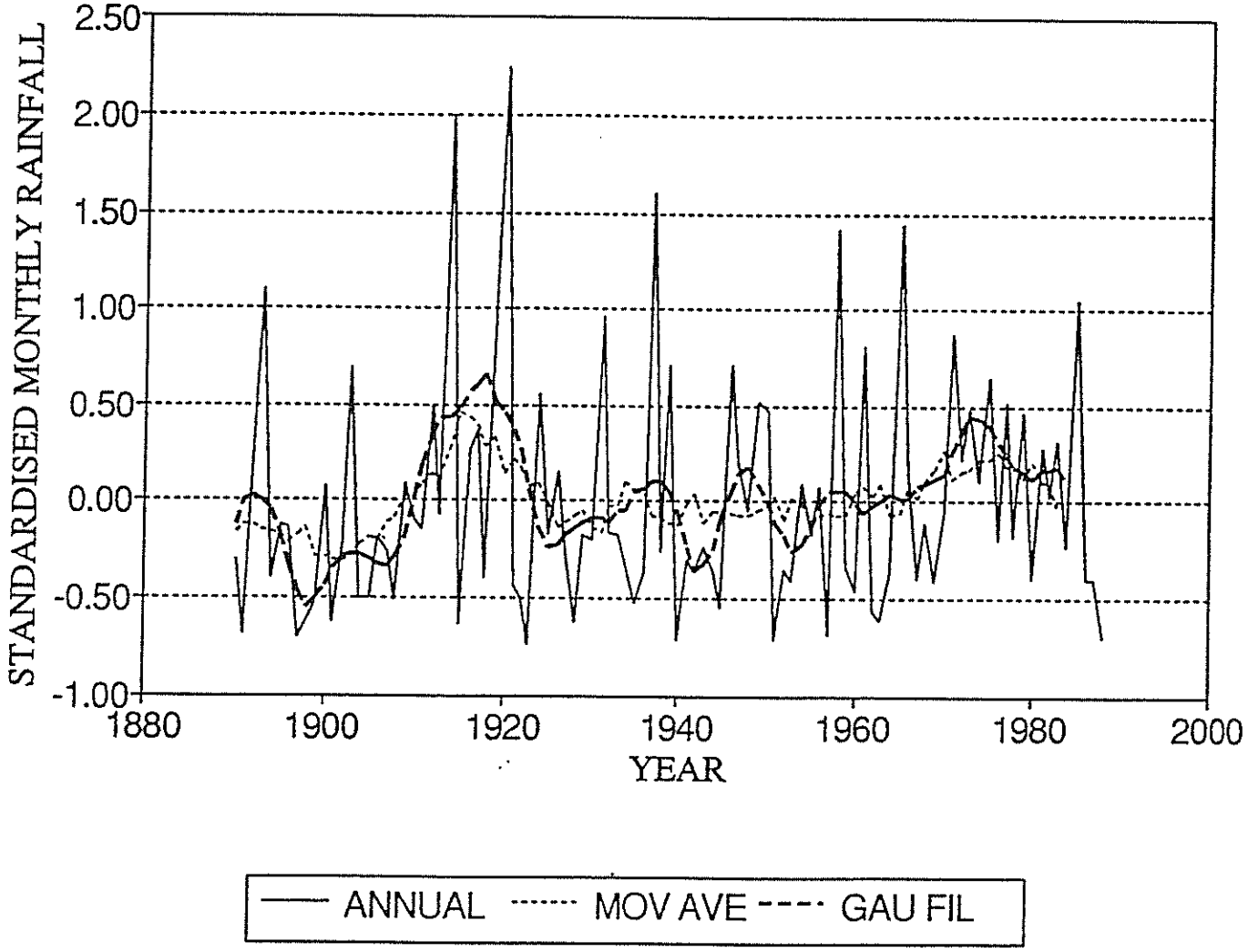


Fig B67 Plot of November rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

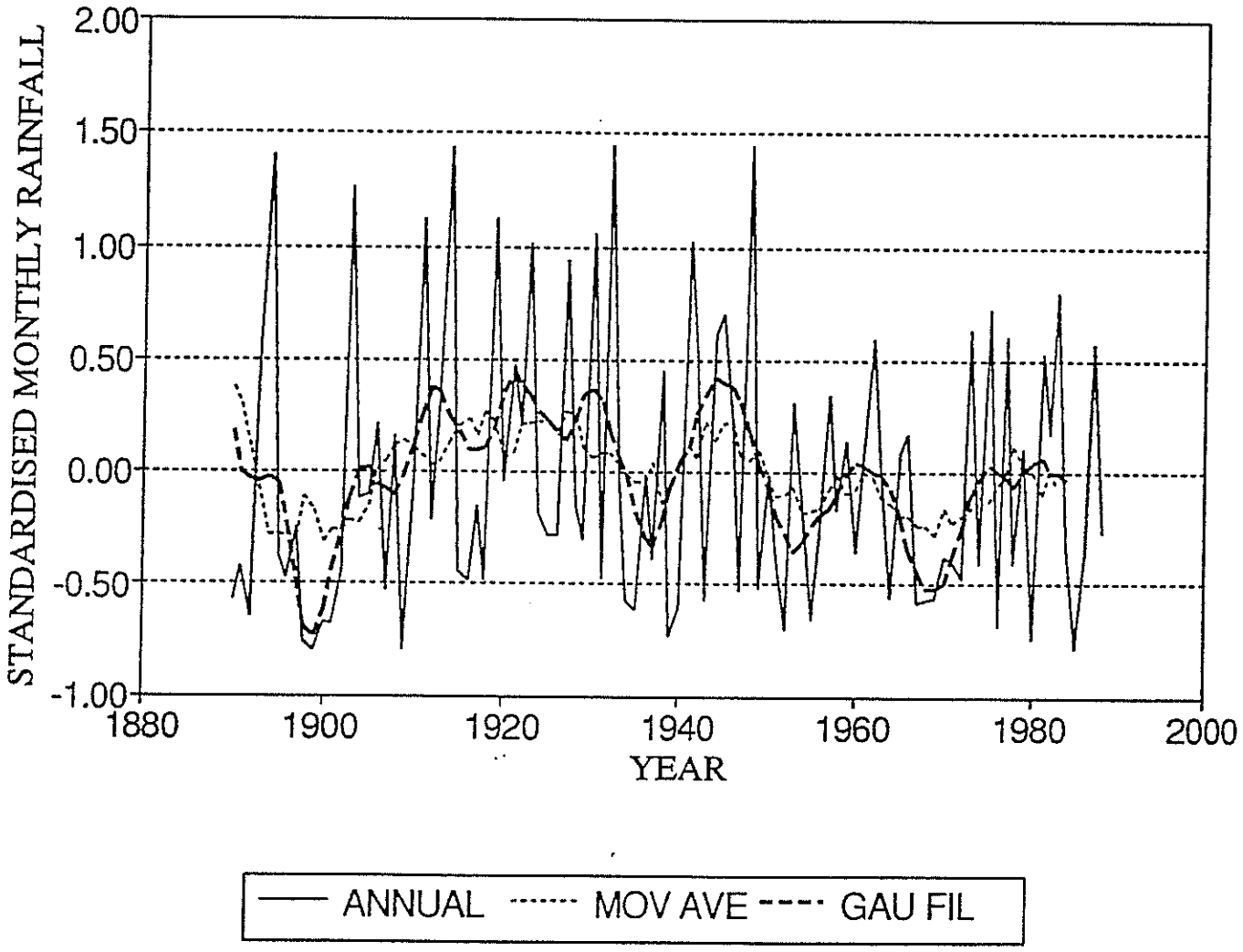


Fig B68 Plot of December rainfall time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

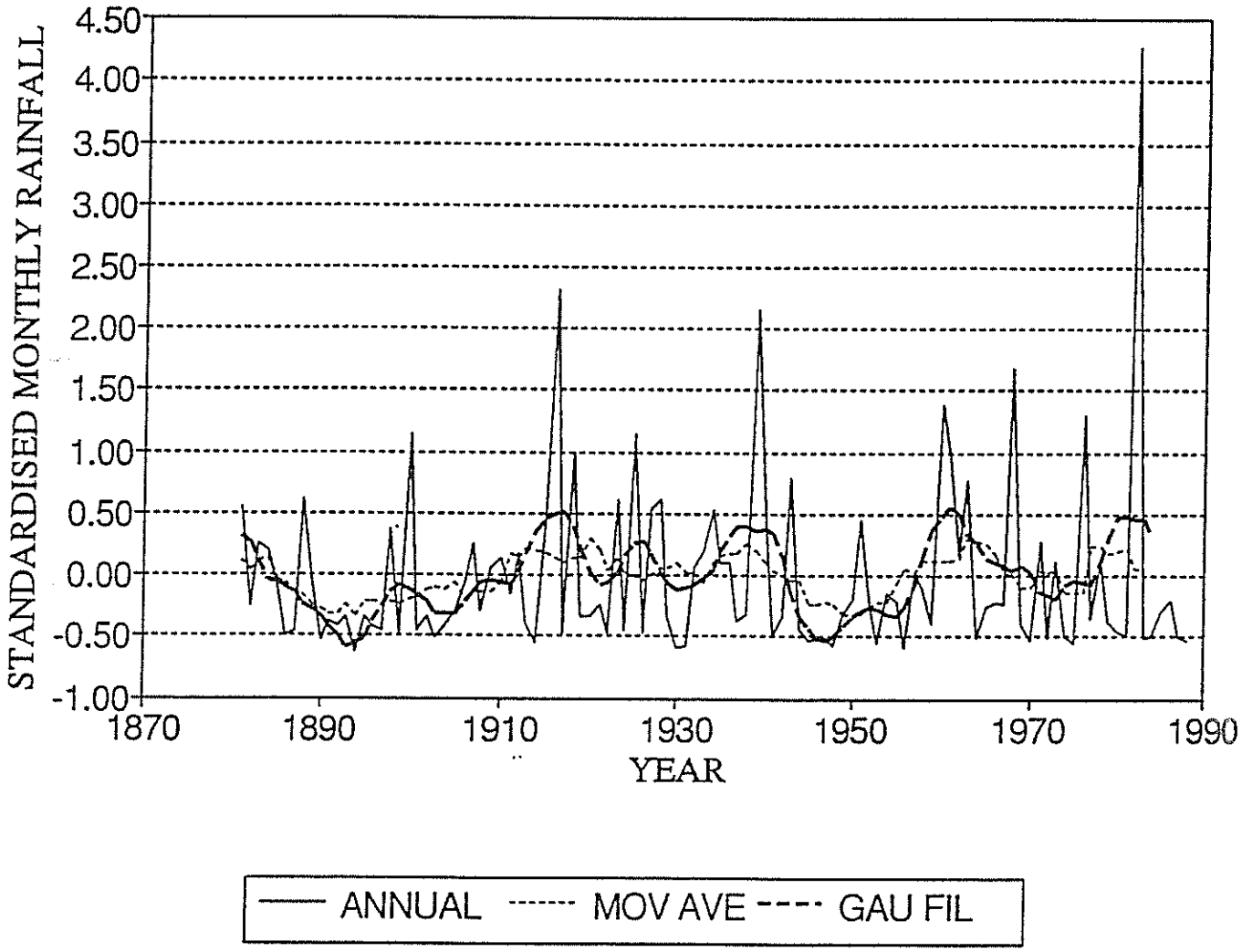


Fig B69 Plot of January rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

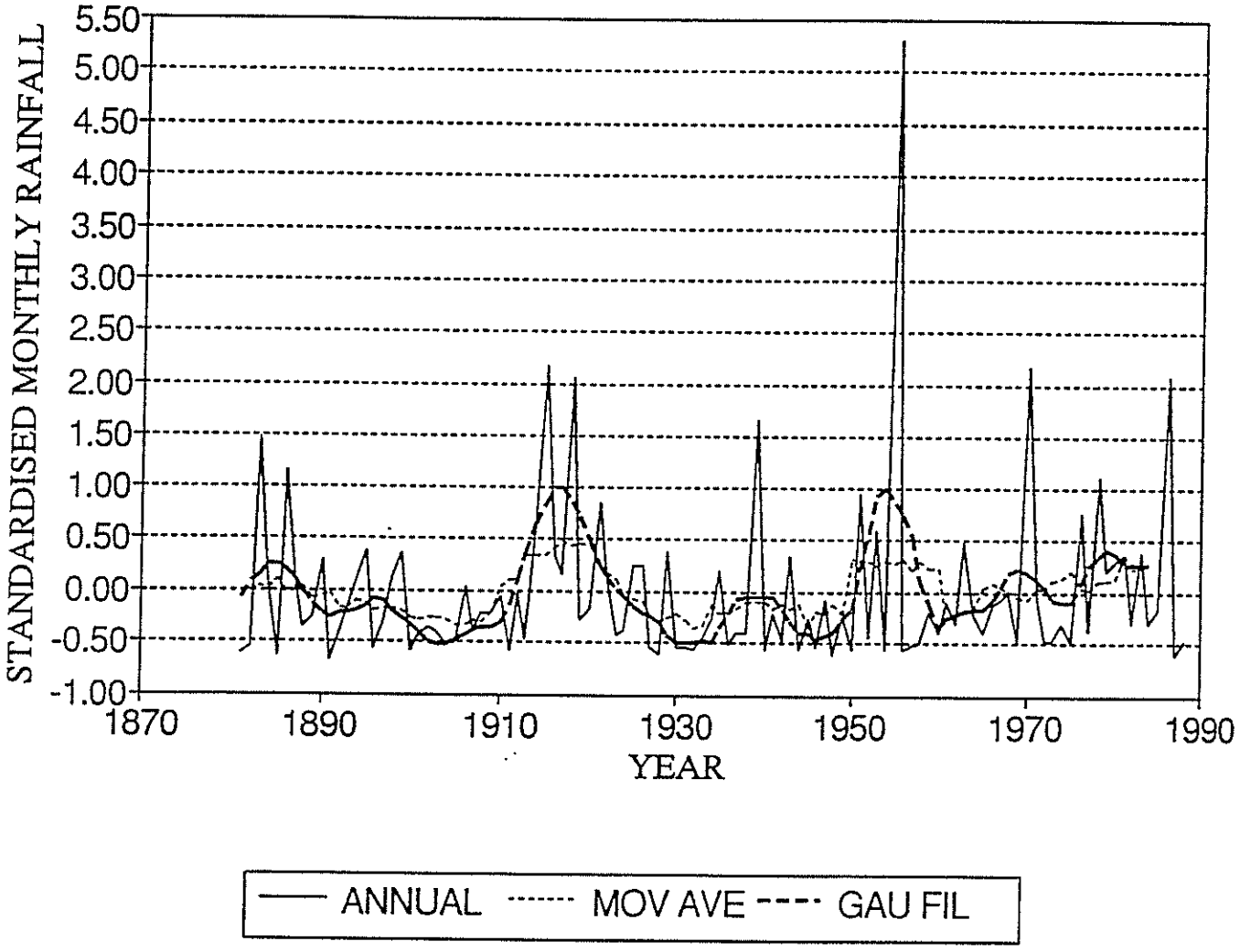


Fig B70 Plot of February rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

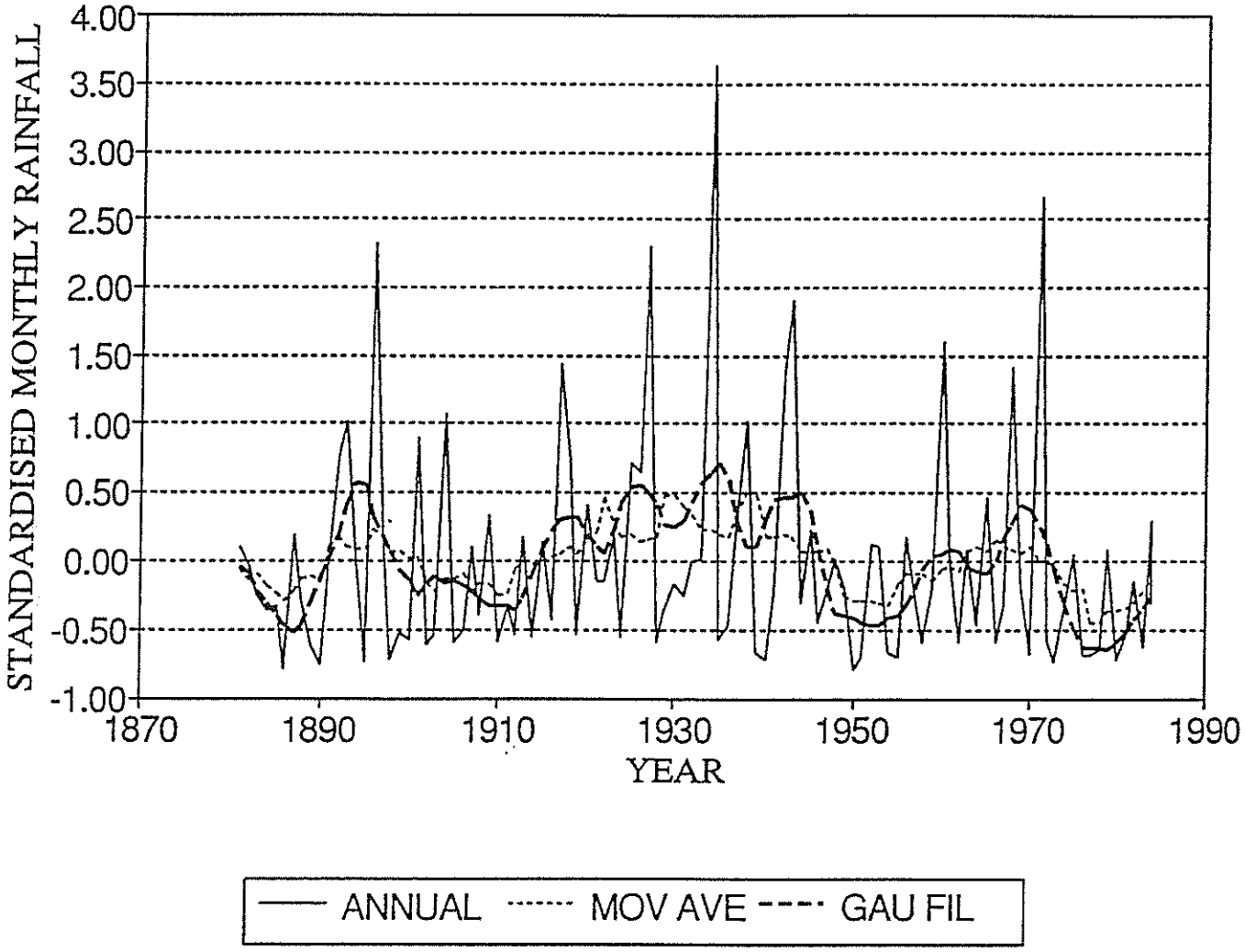


Fig B71 Plot of March rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

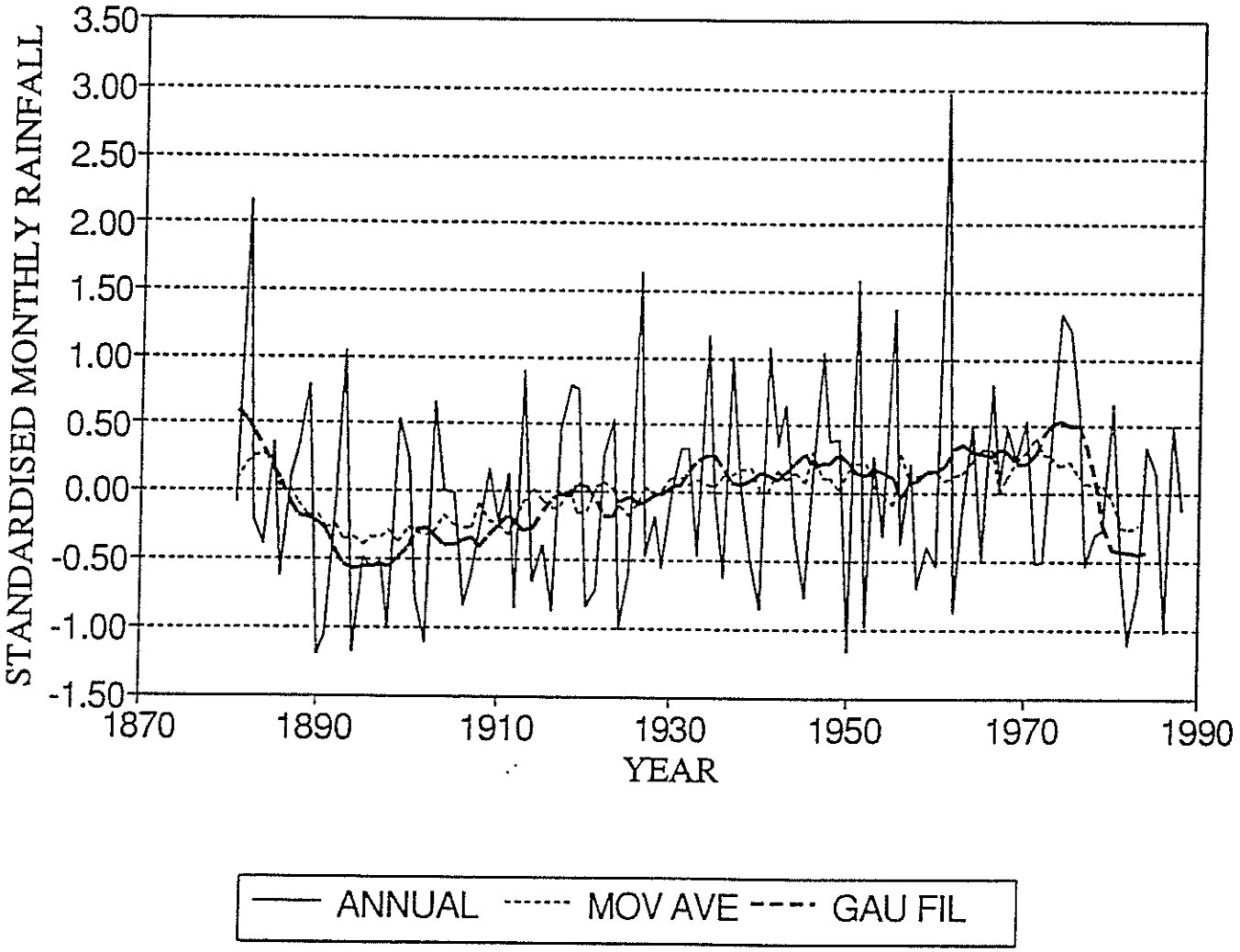


Fig B72 Plot of April rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

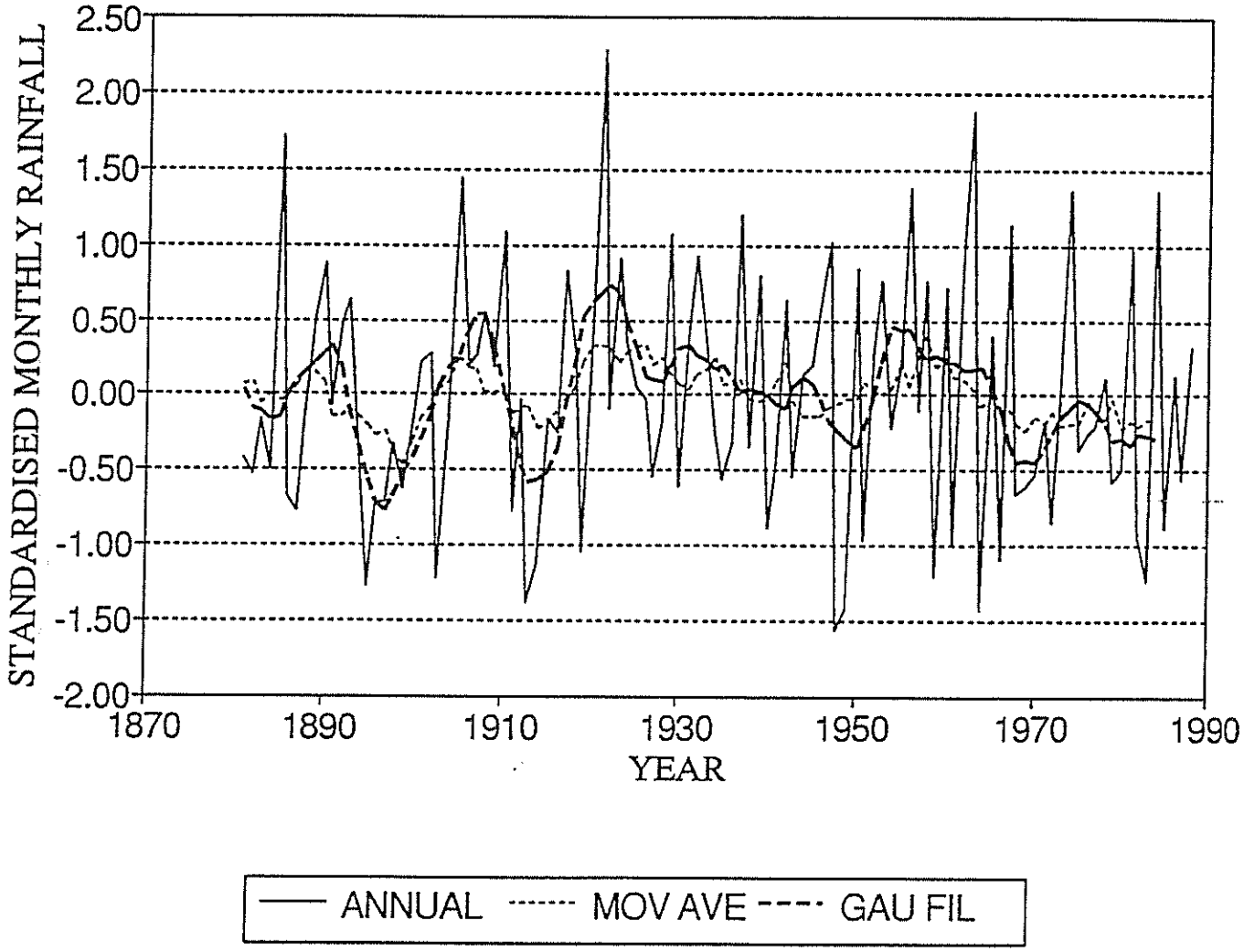


Fig B73 Plot of May rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

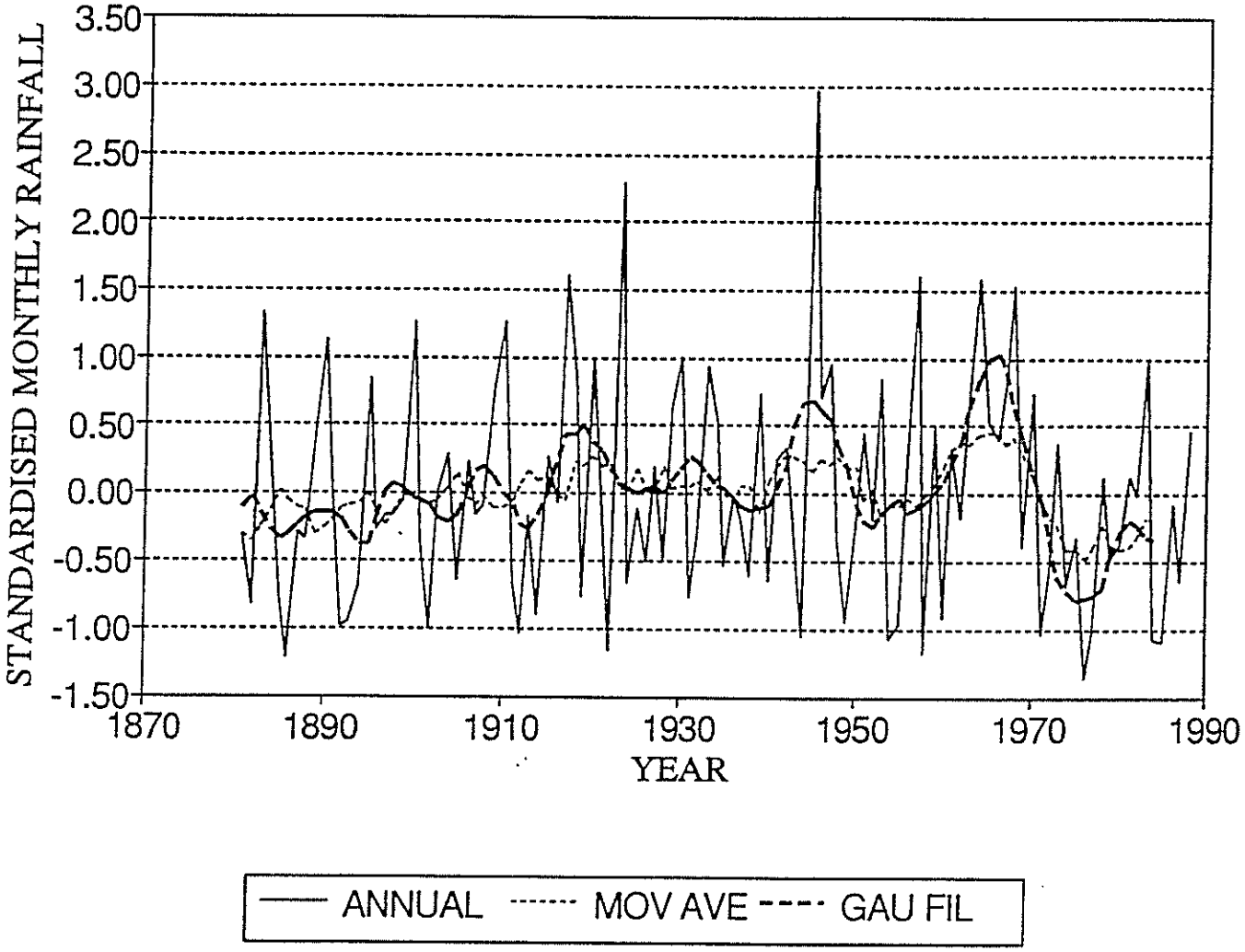


Fig B74 Plot of June rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

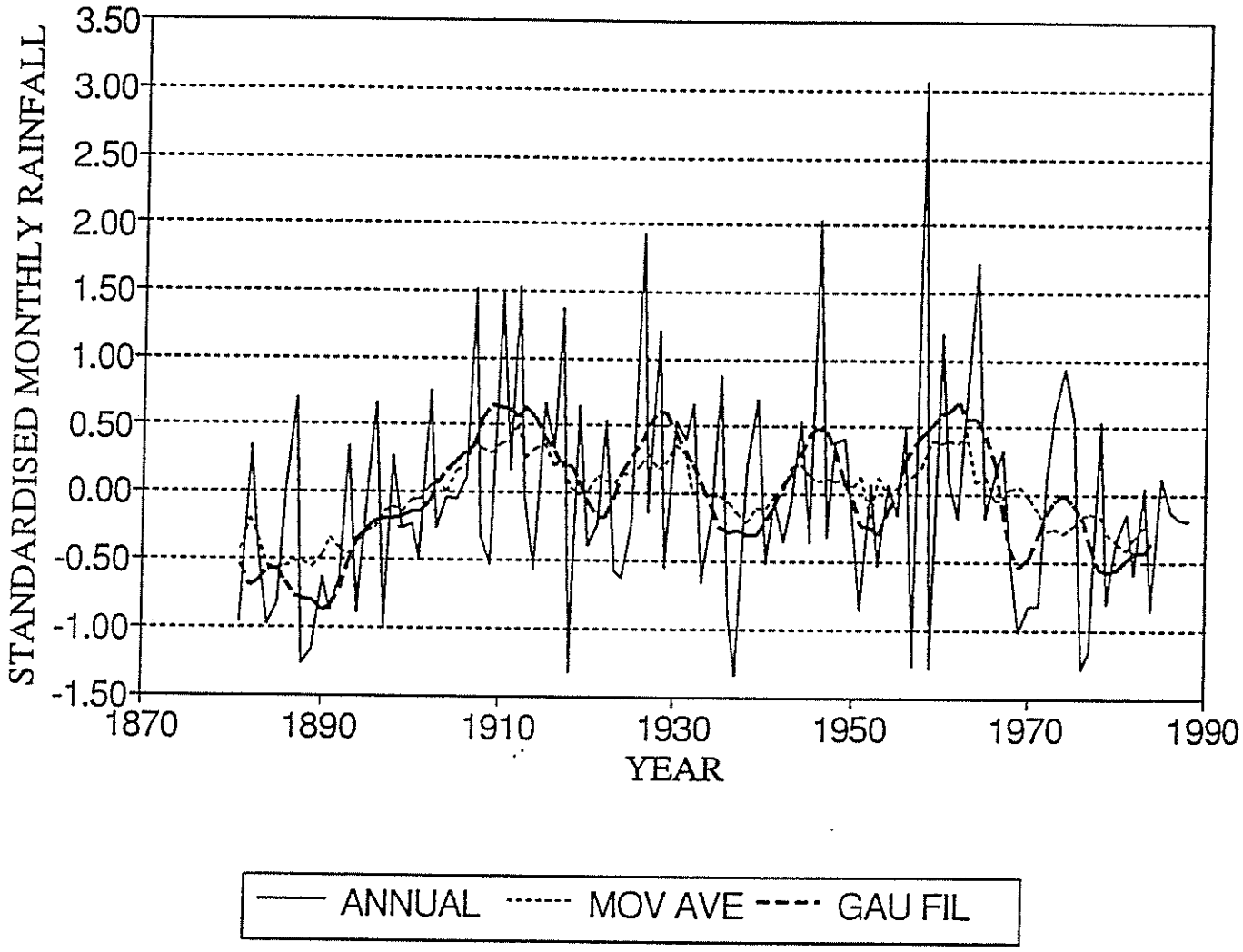


Fig B75 Plot of July rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

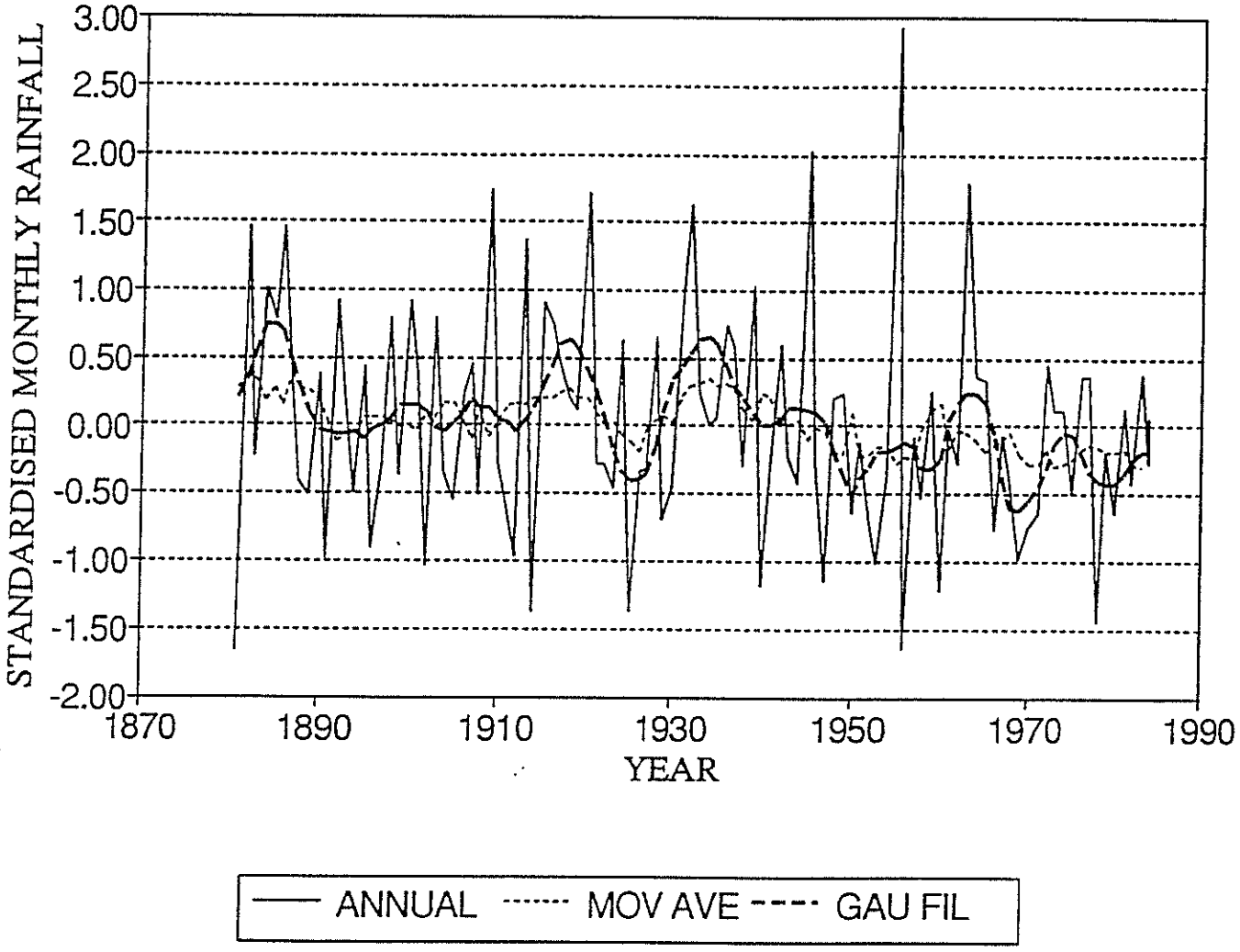


Fig B76 Plot of August rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

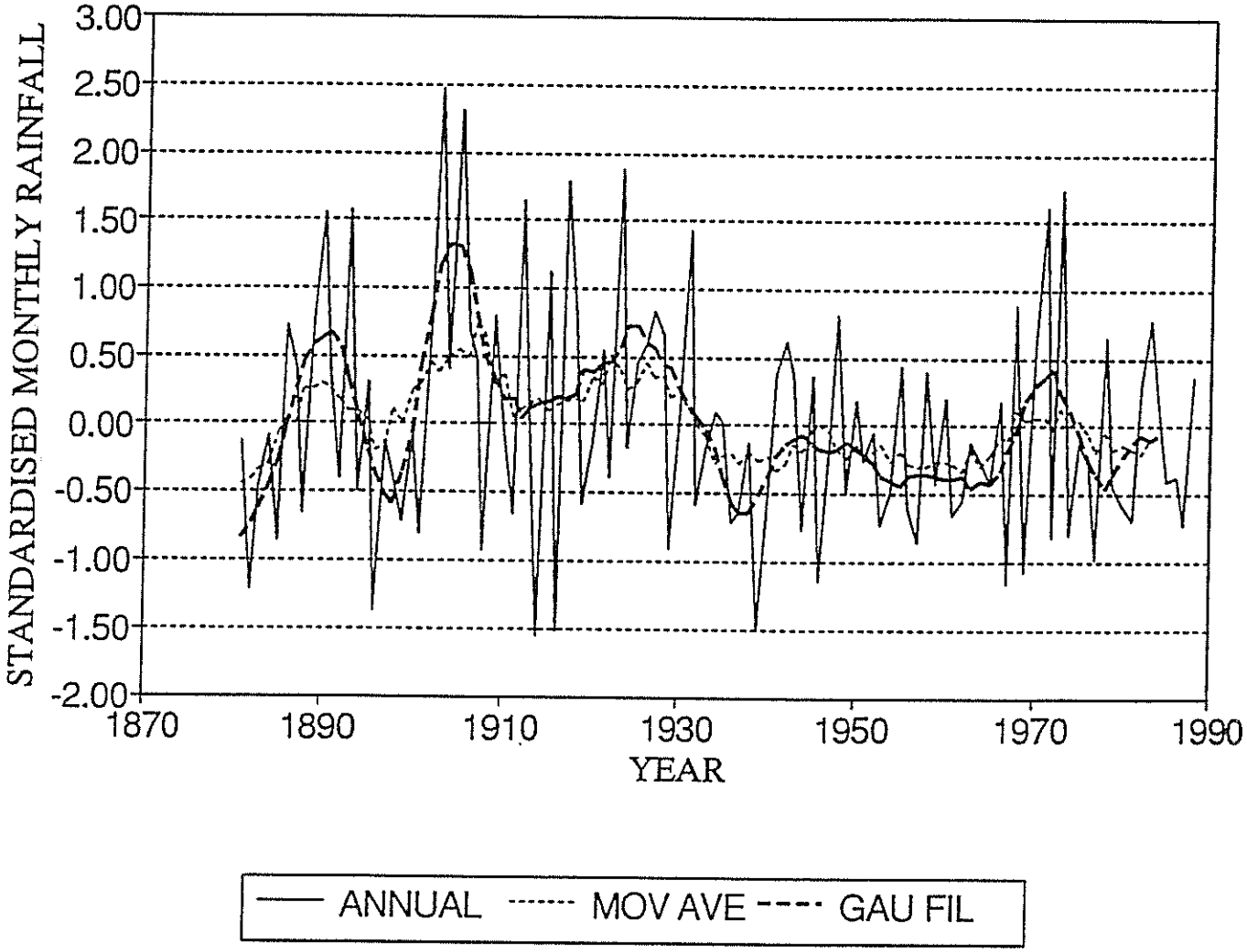


Fig B77 Plot of September rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

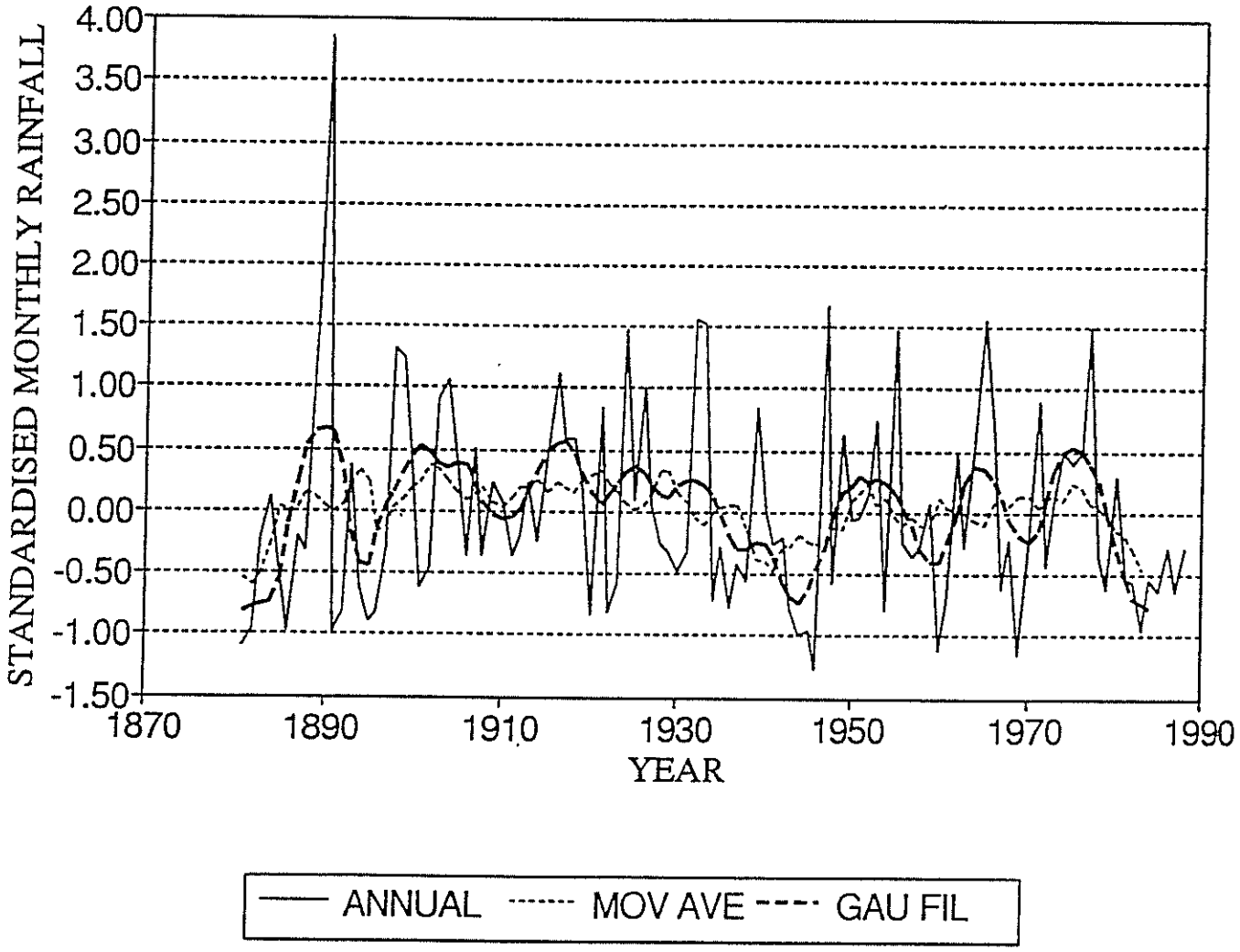


Fig B78 Plot of October rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

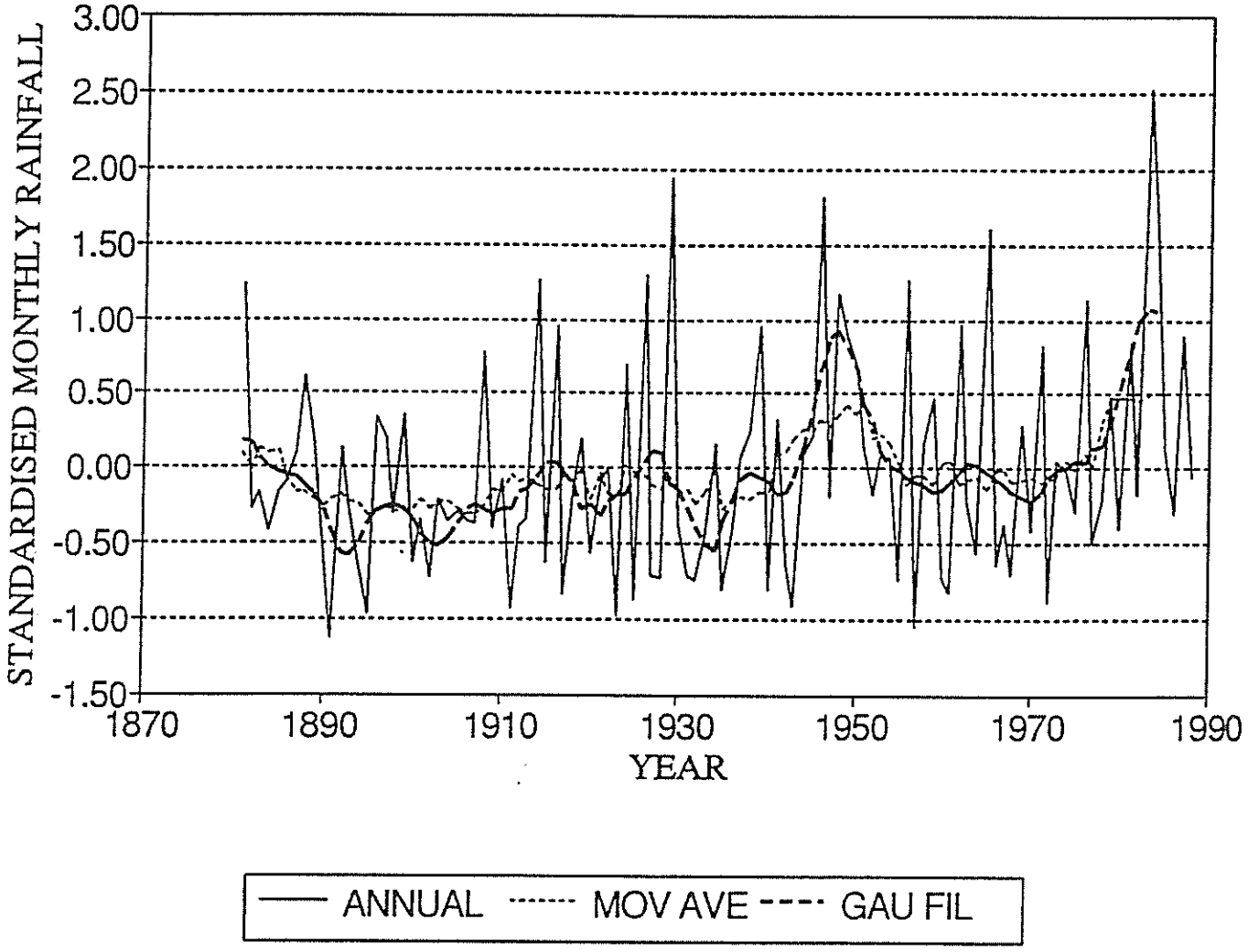


Fig B79 Plot of November rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

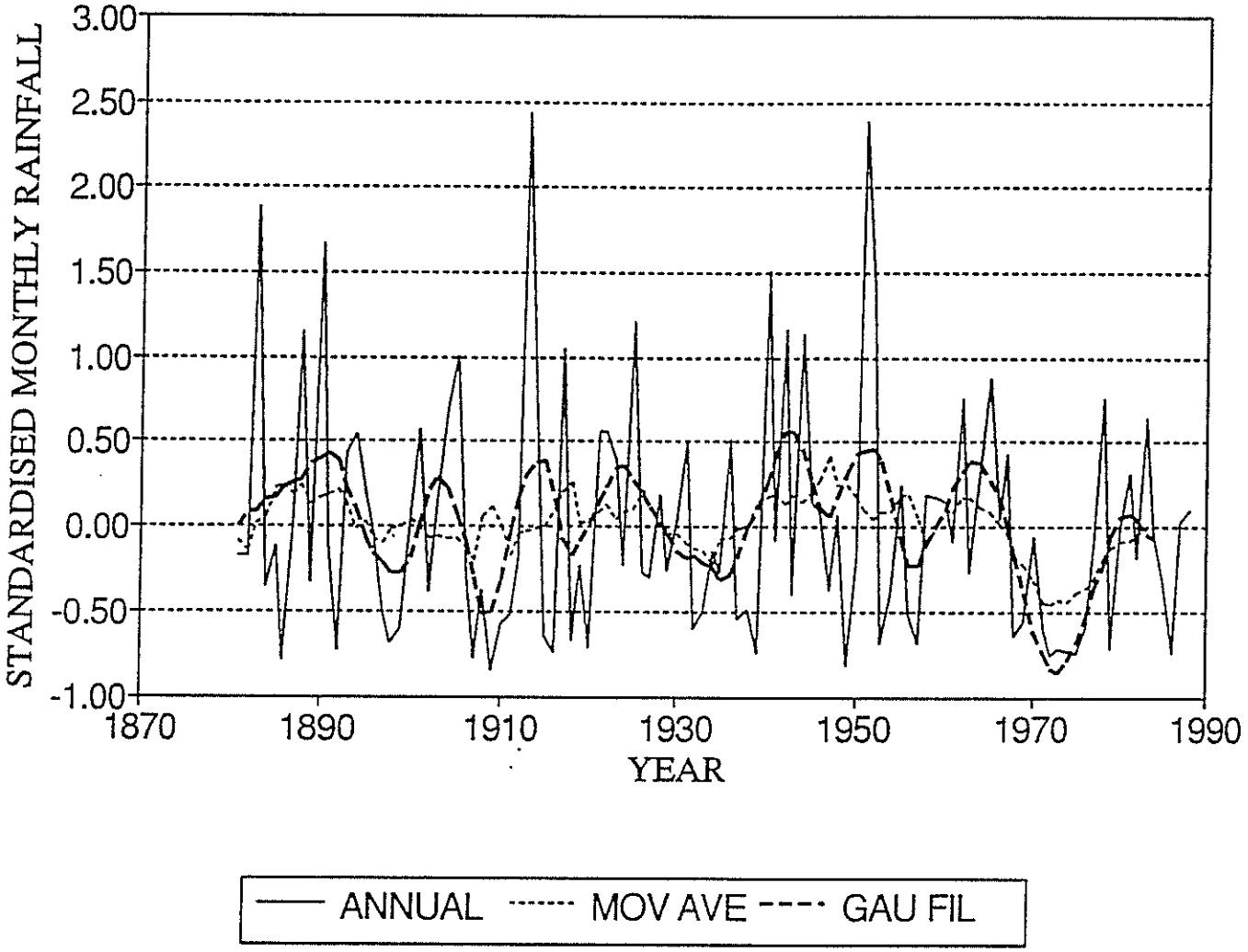


Fig B80 Plot of December rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

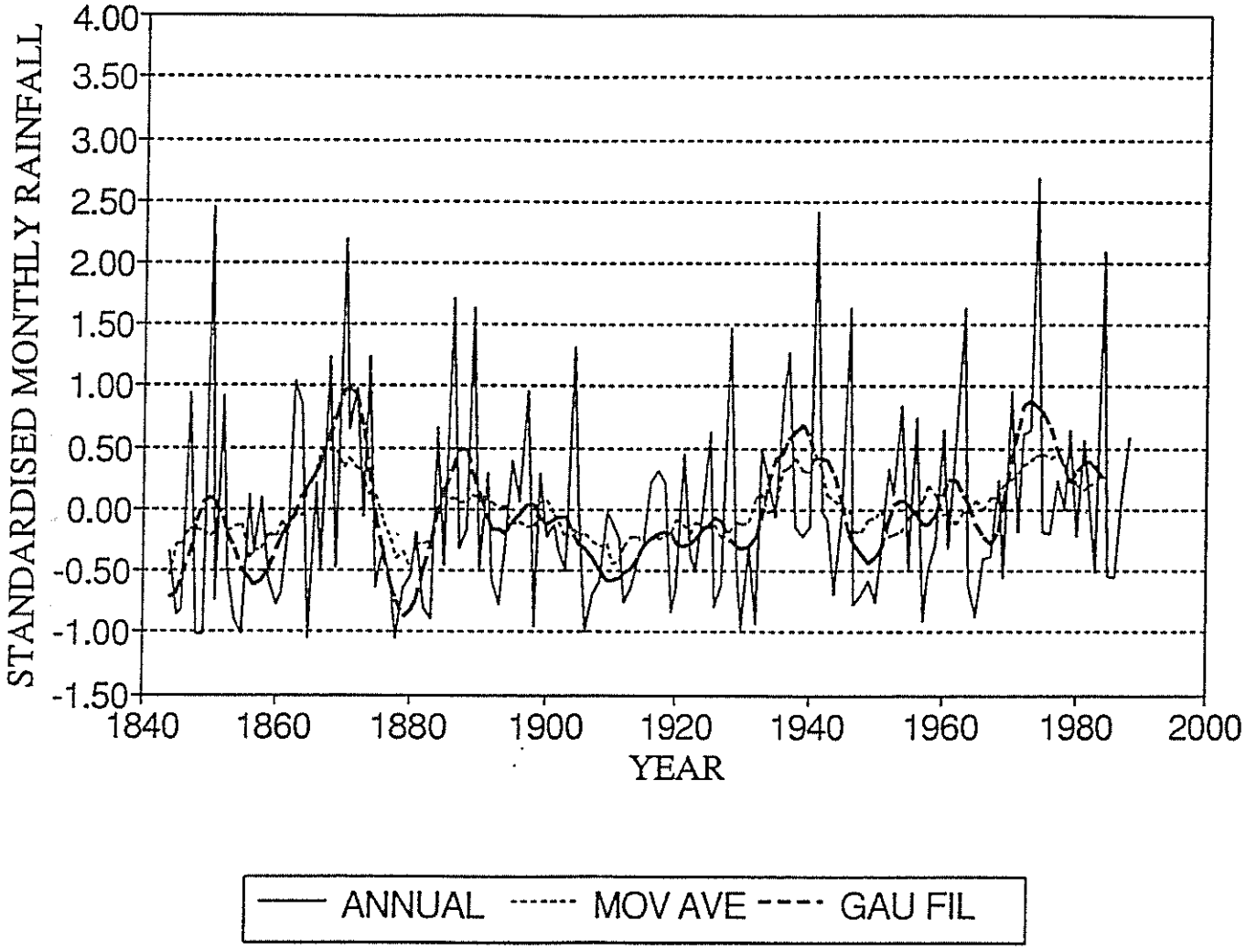


Fig B81 Plot of January rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

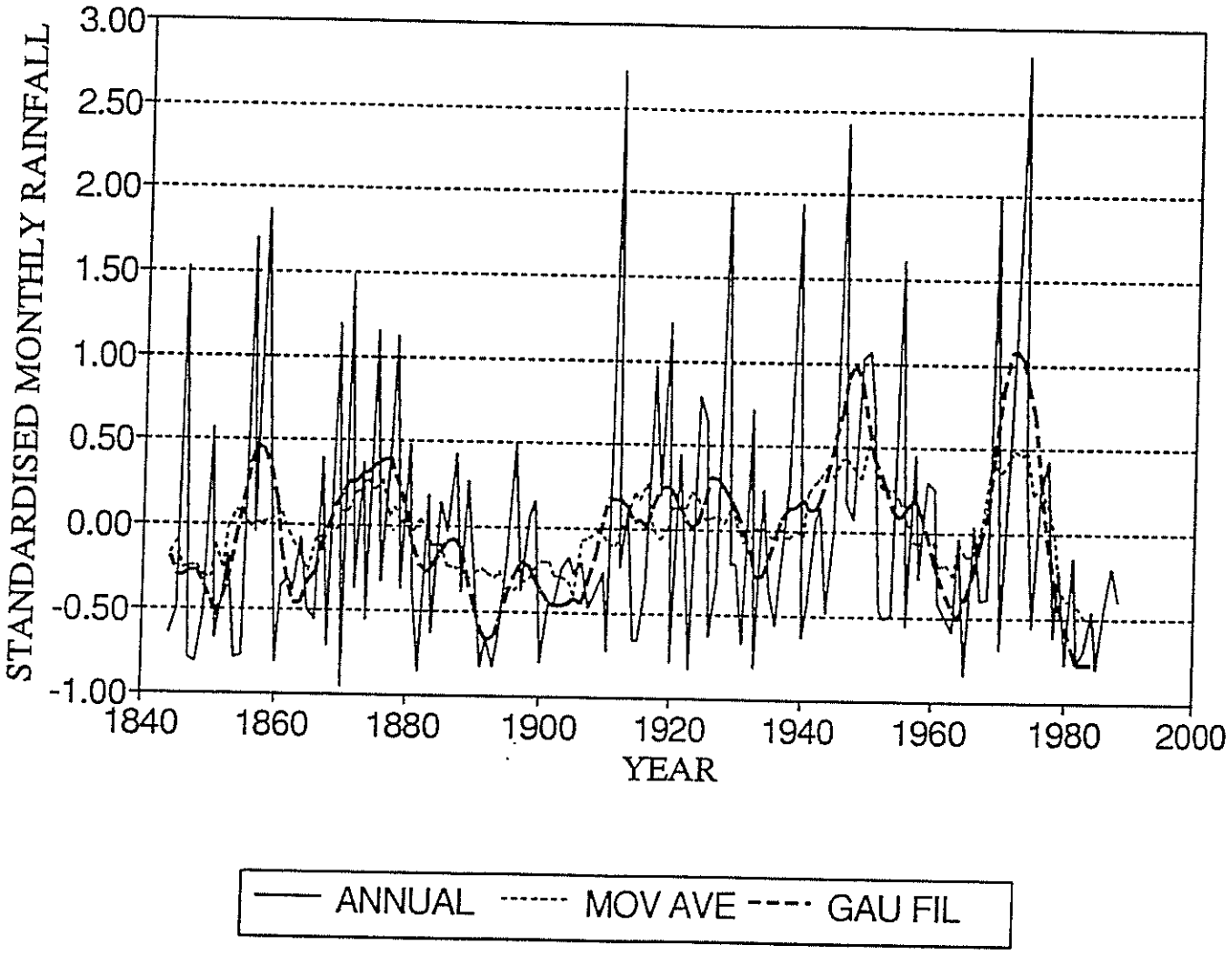


Fig B82 Plot of February rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

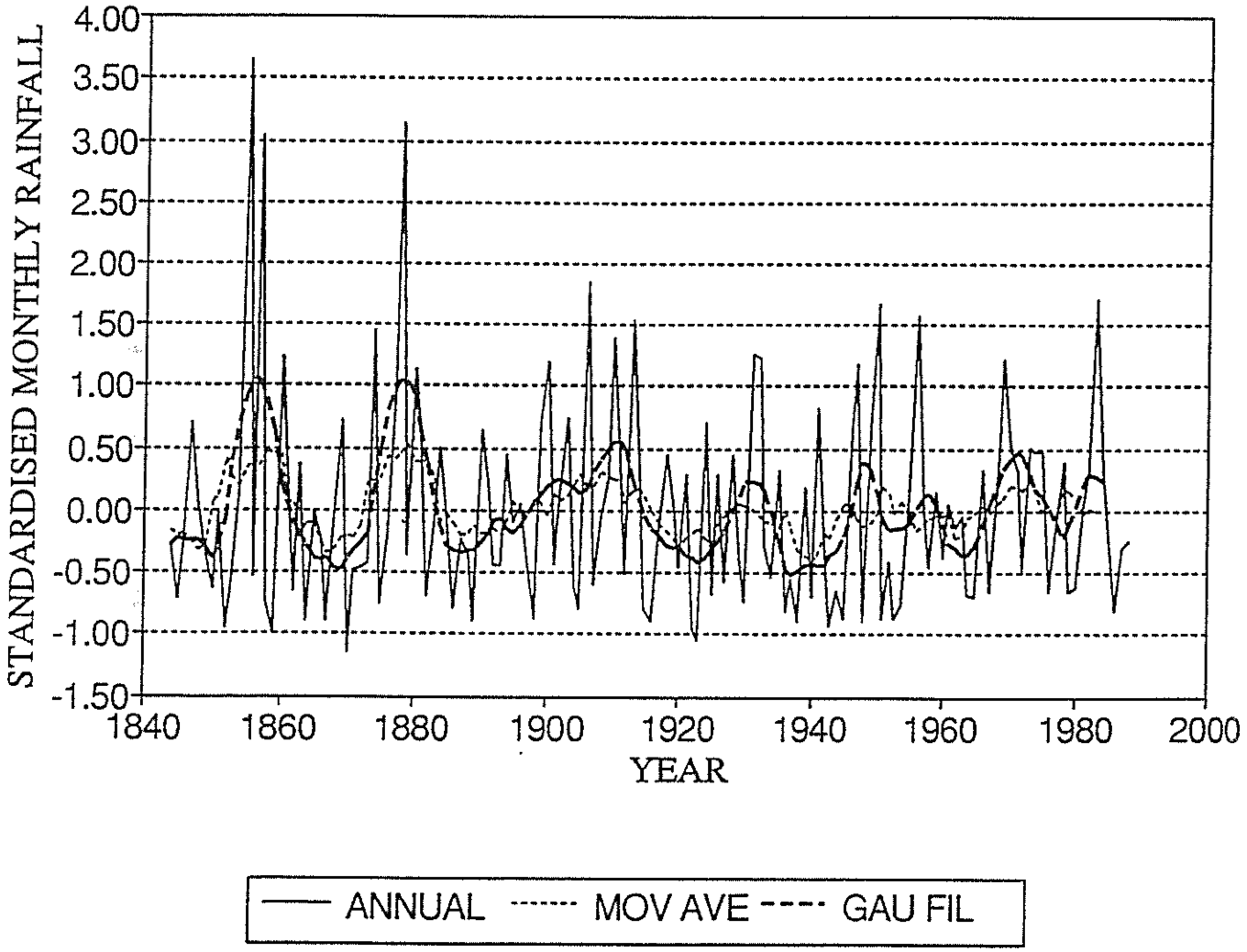


Fig B83 Plot of March rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

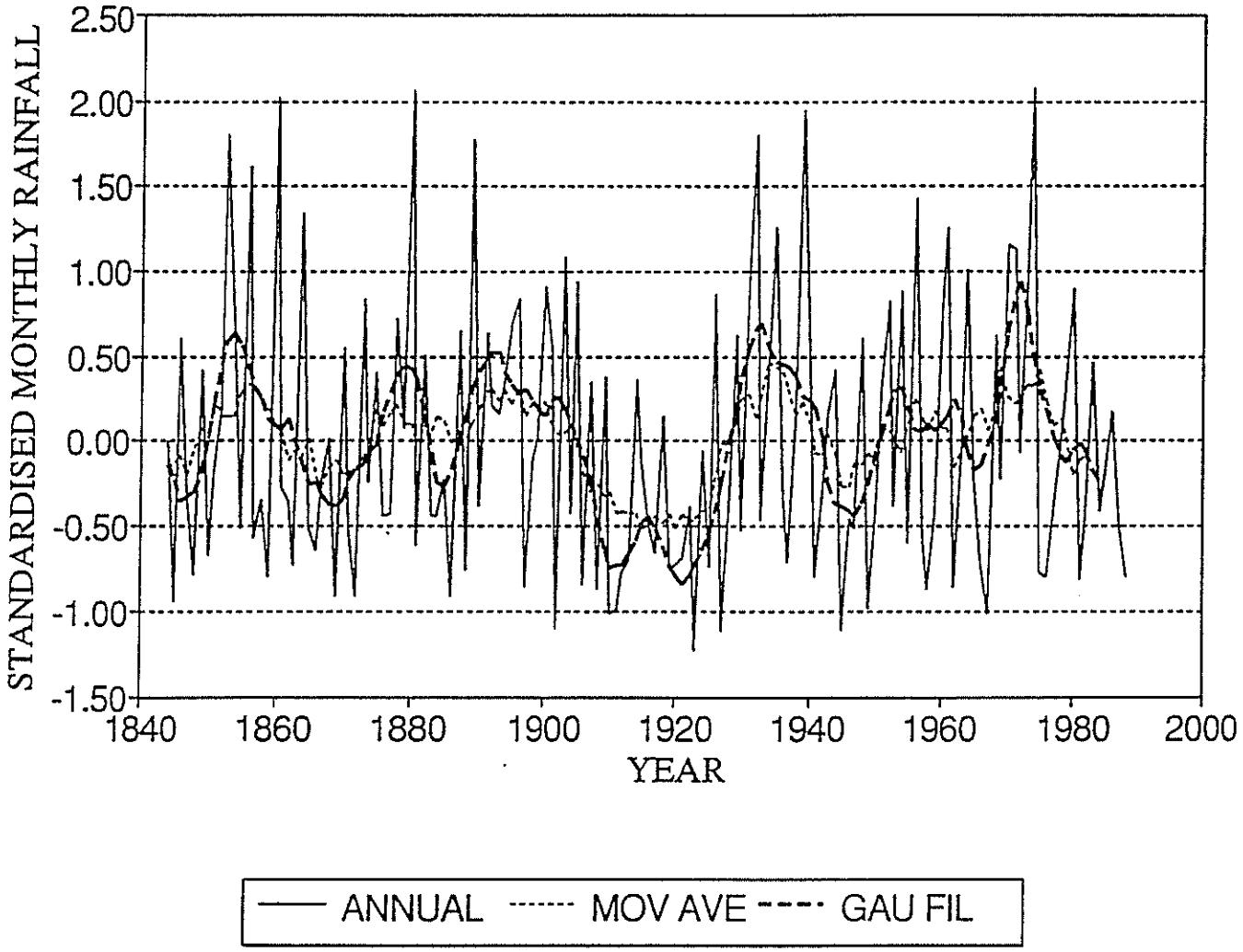


Fig B84 Plot of April rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

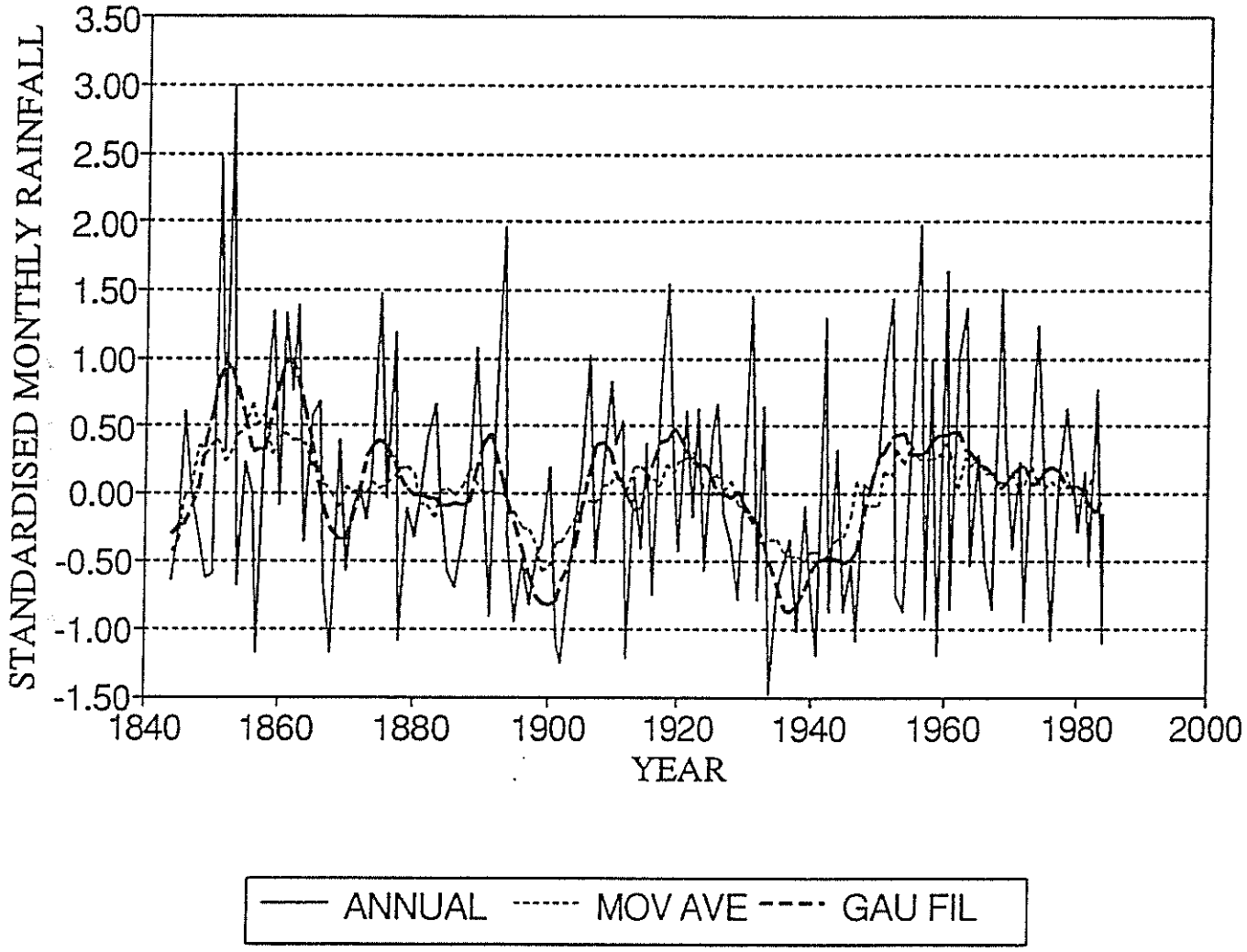


Fig B85 Plot of May rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

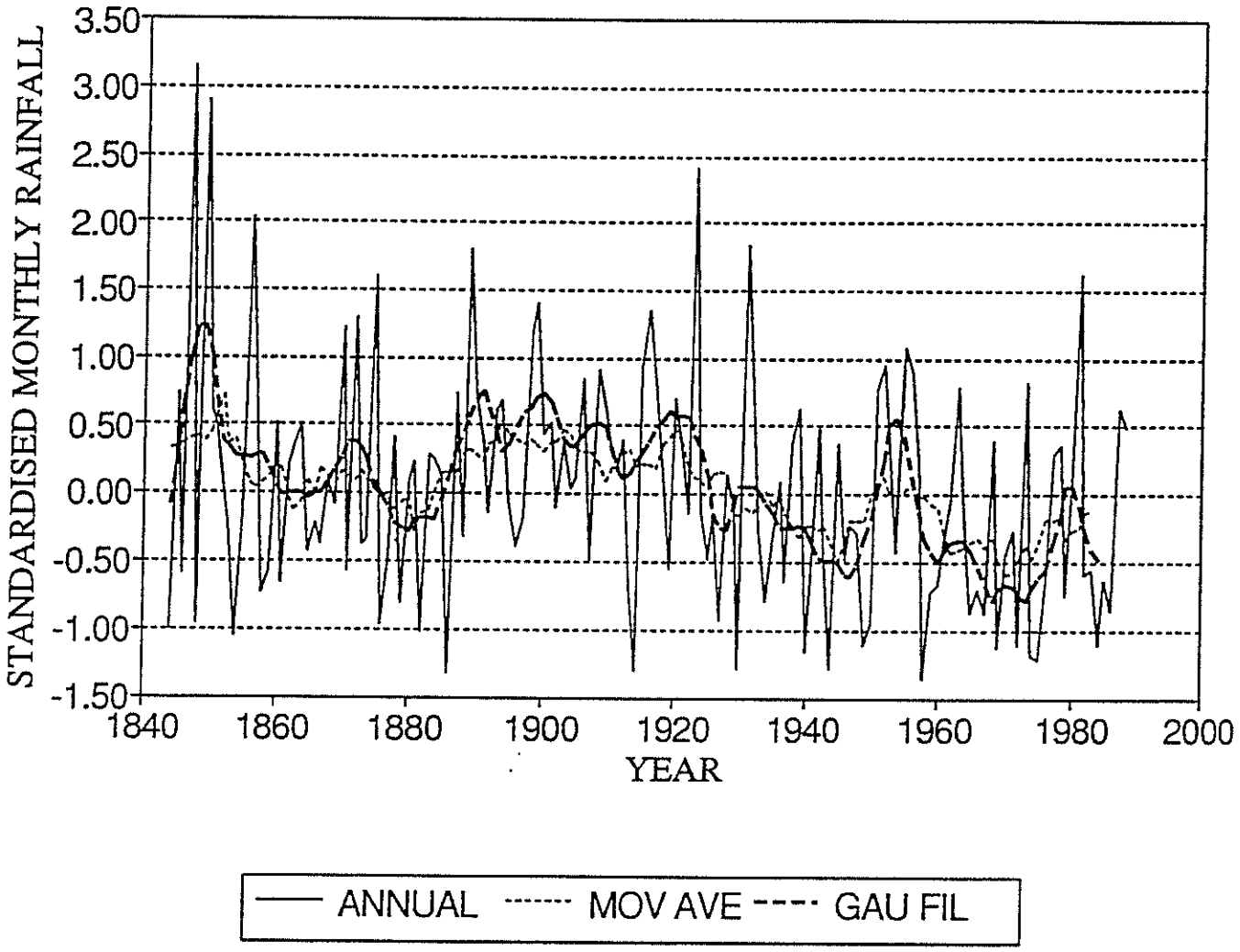


Fig B86 Plot of June rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

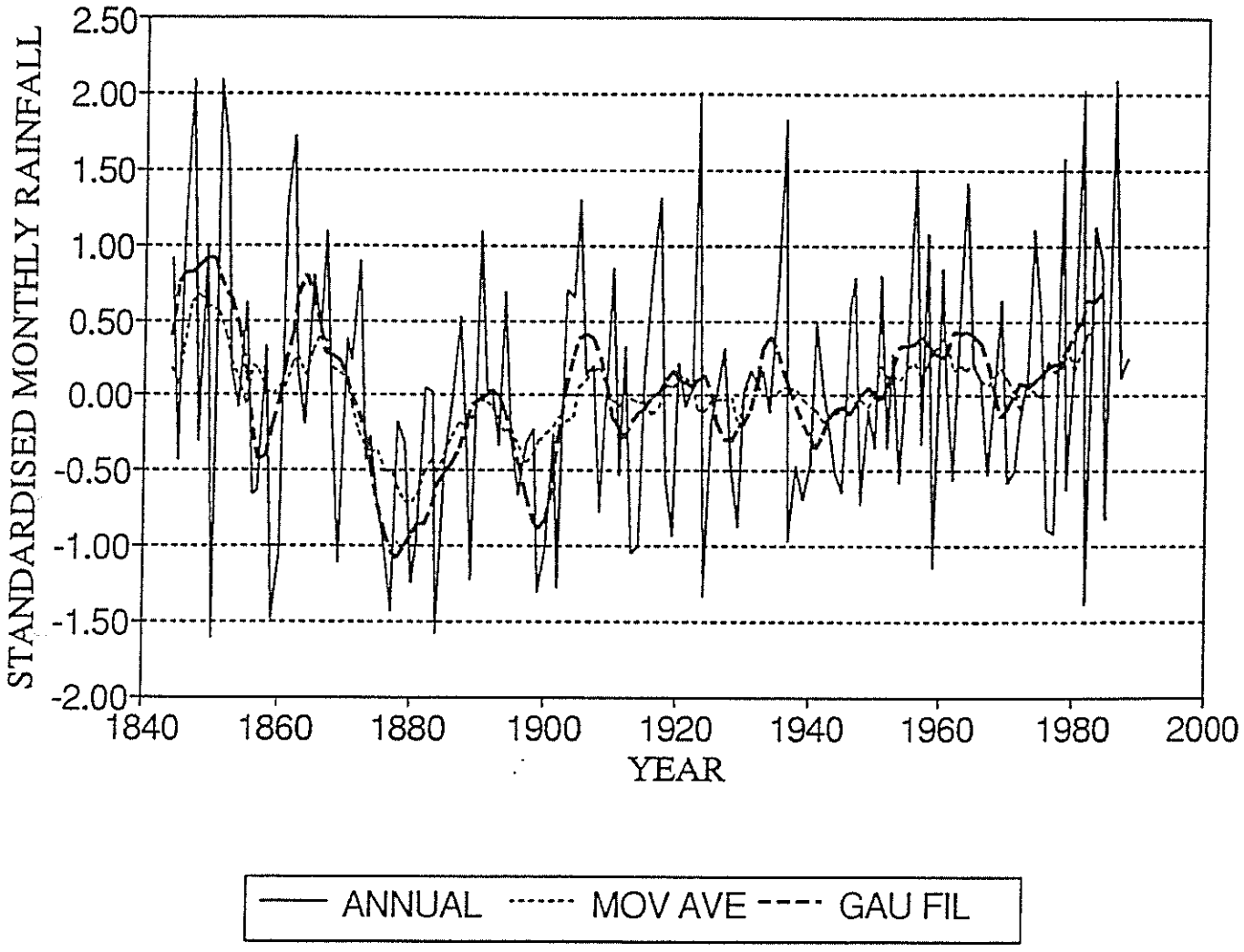


Fig B87 Plot of July rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

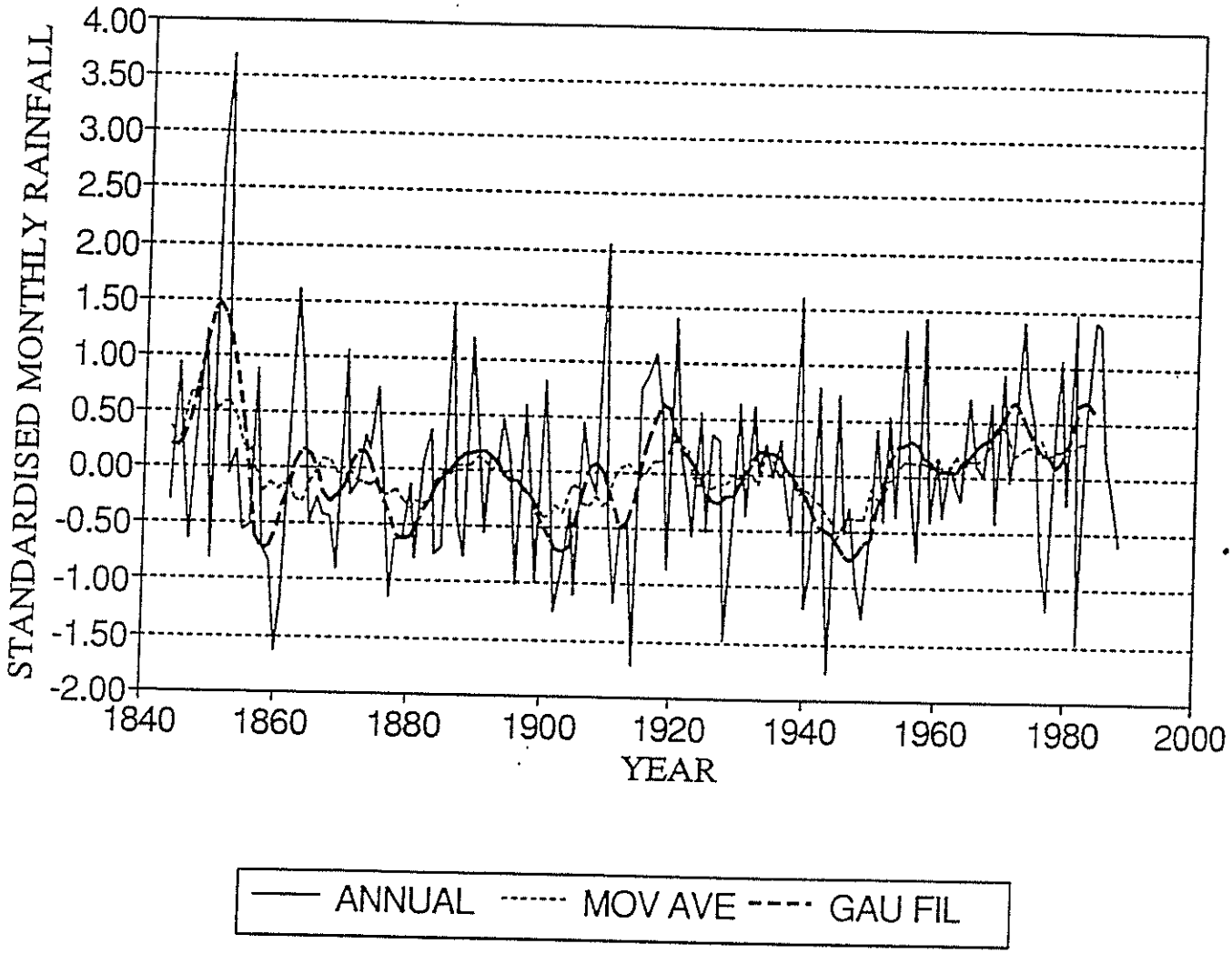


Fig B88 Plot of August rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

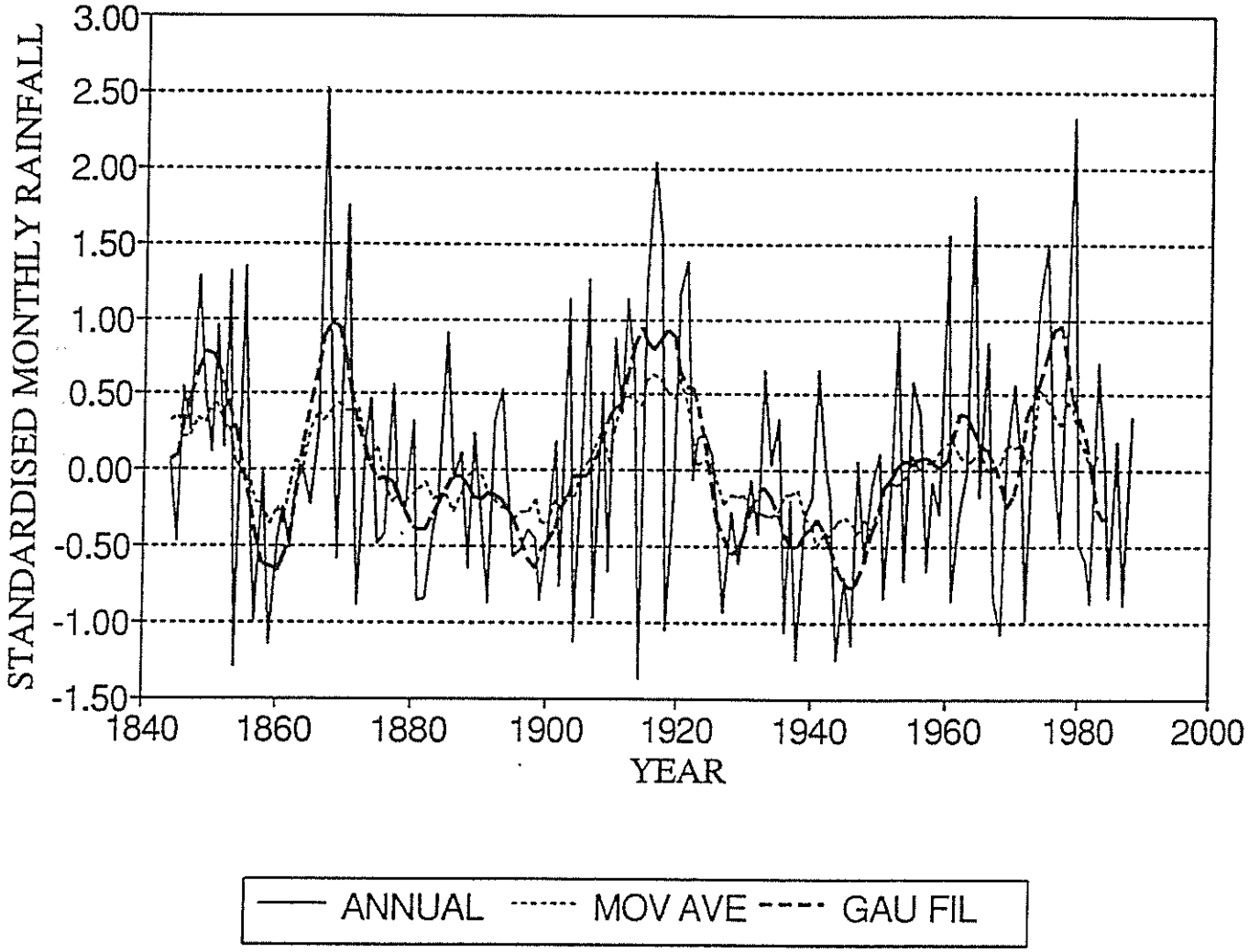


Fig B89 Plot of September rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

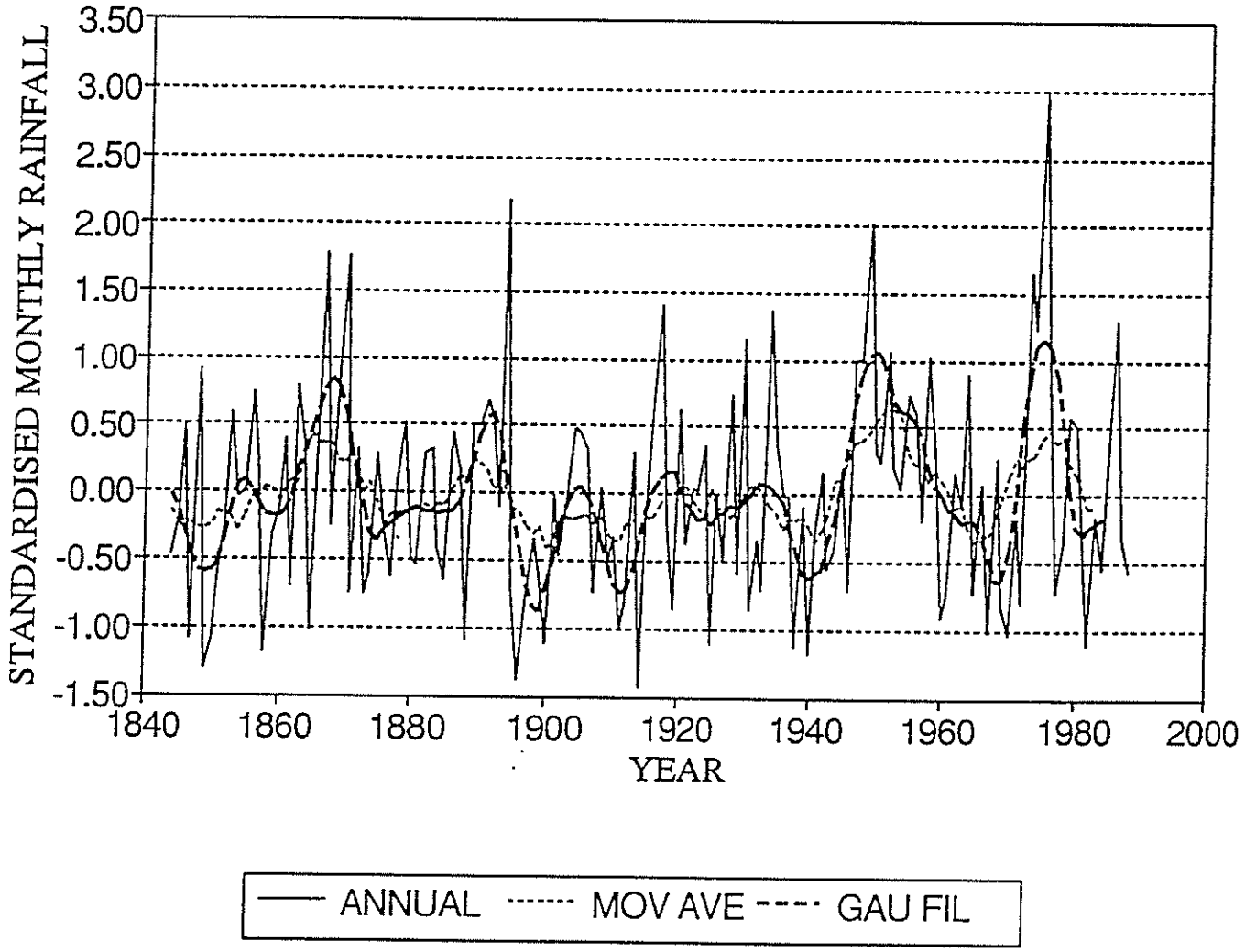


Fig B90 Plot of October rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

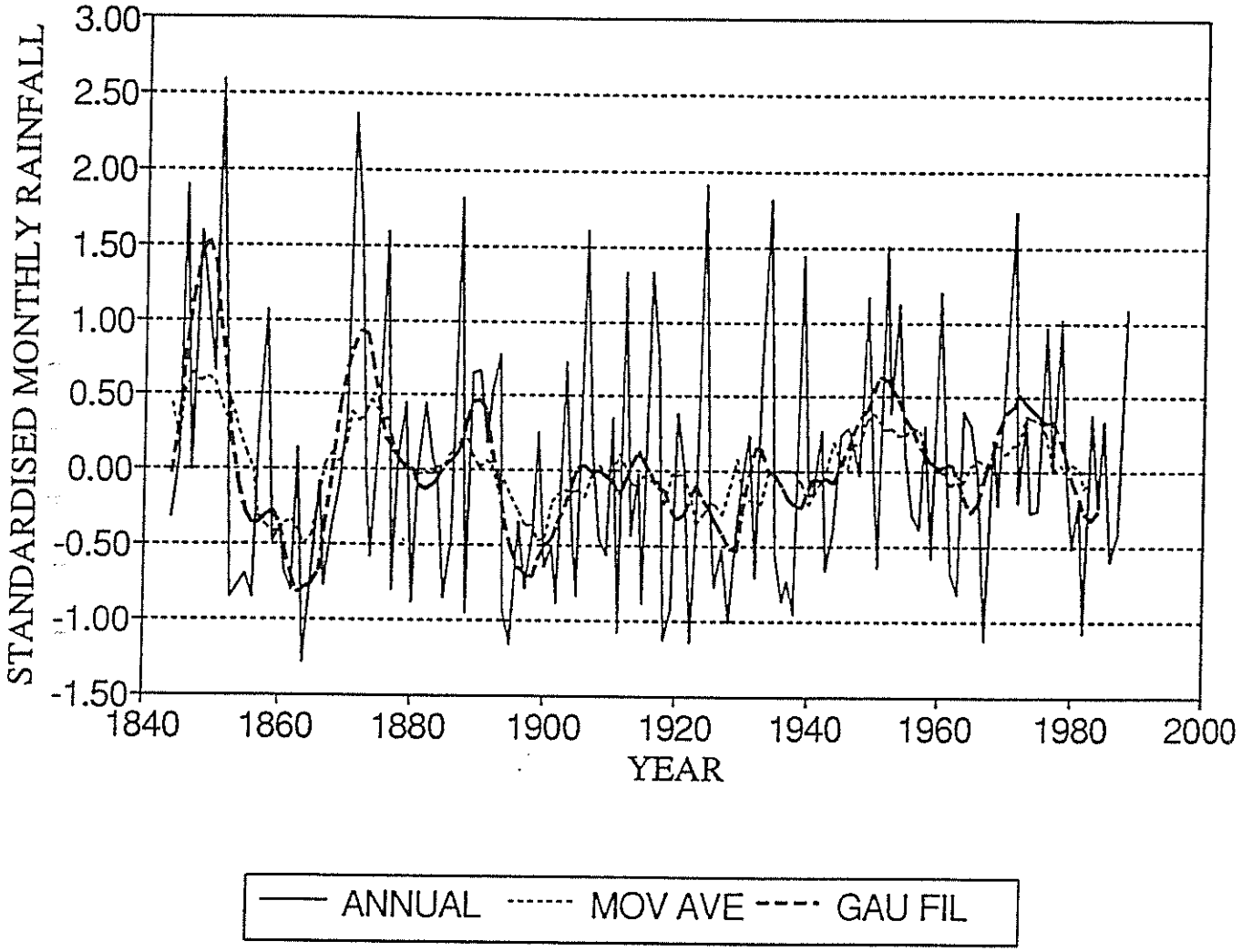


Fig B91 Plot of November rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

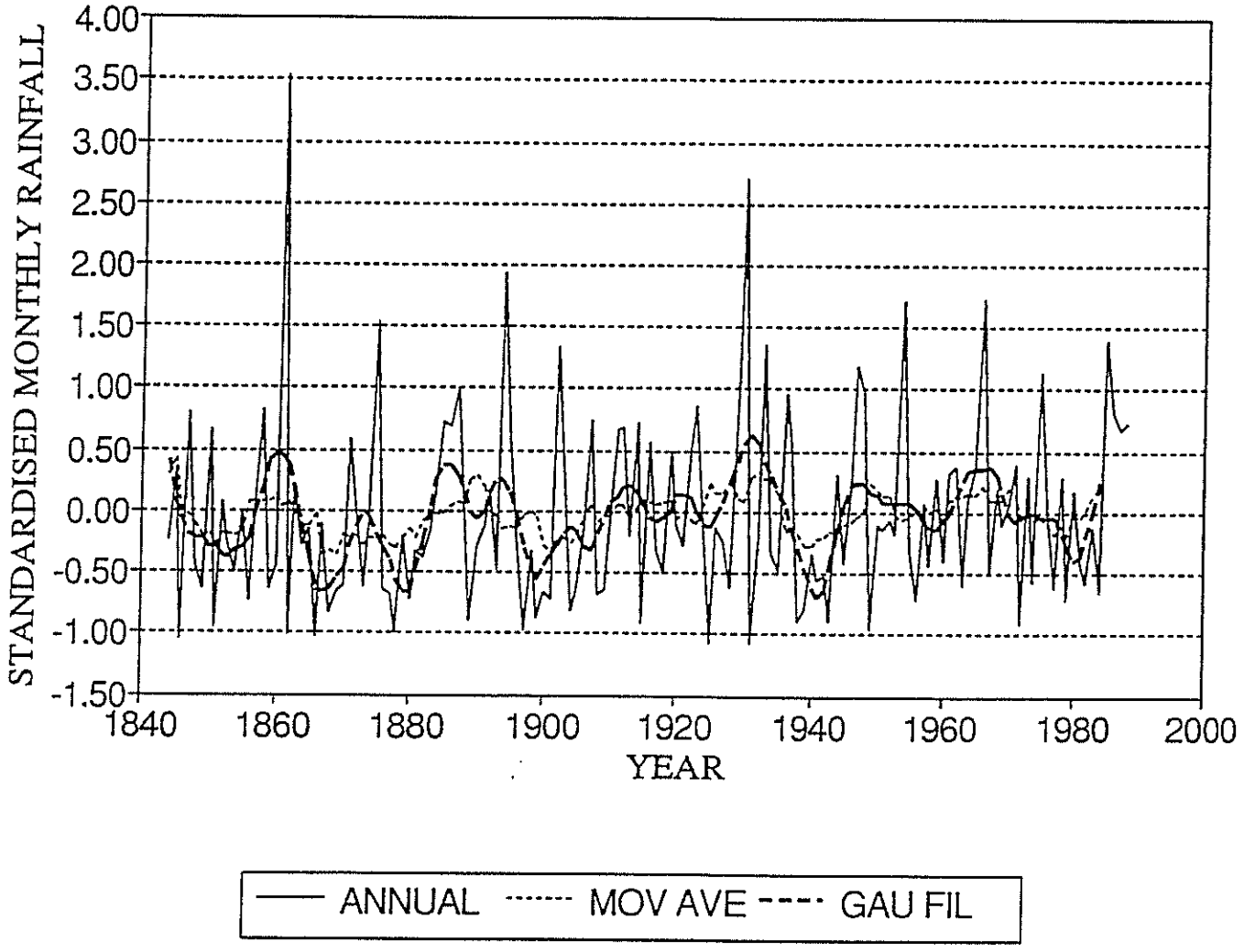


Fig B92 Plot of December rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

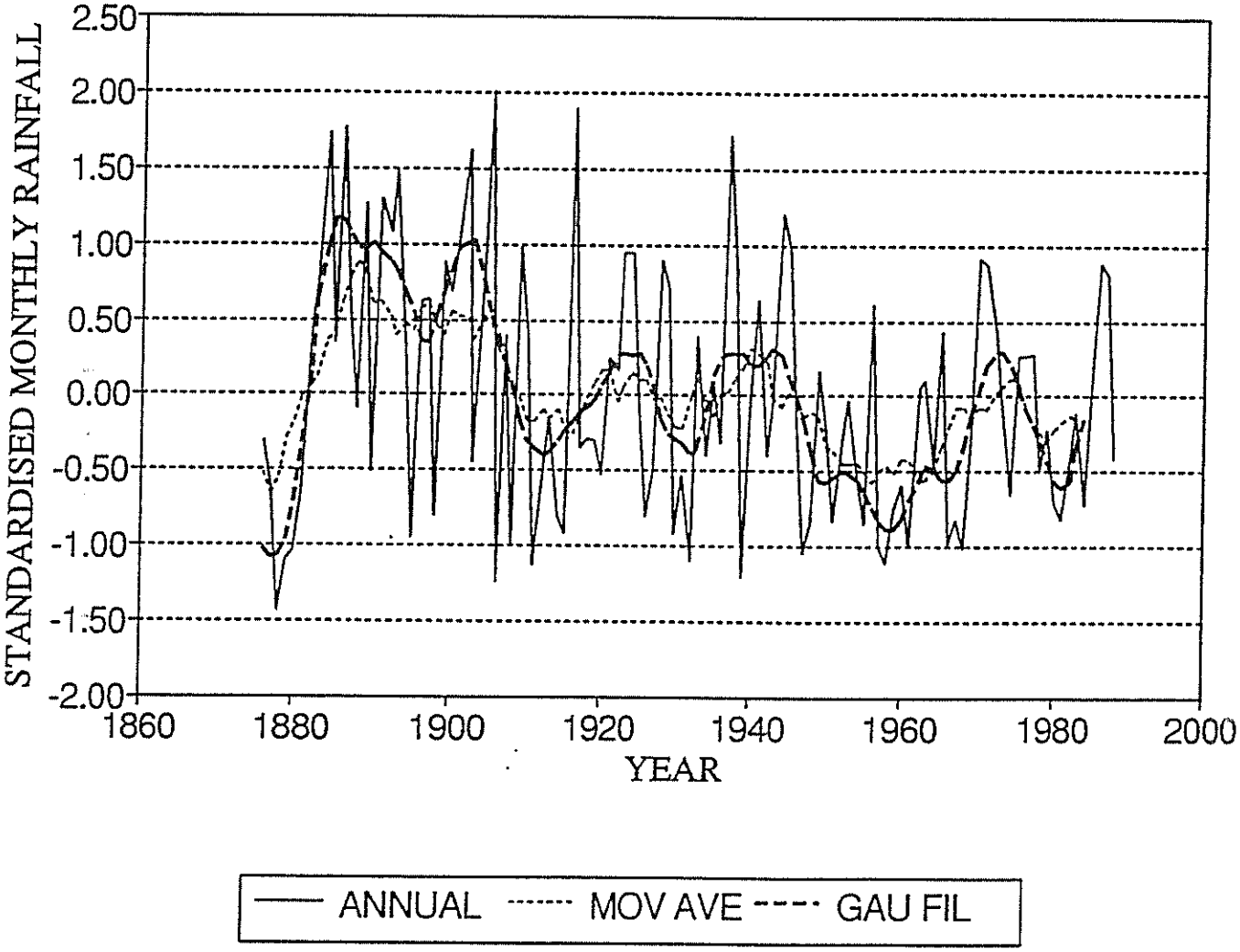


Fig B93 Plot of January rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

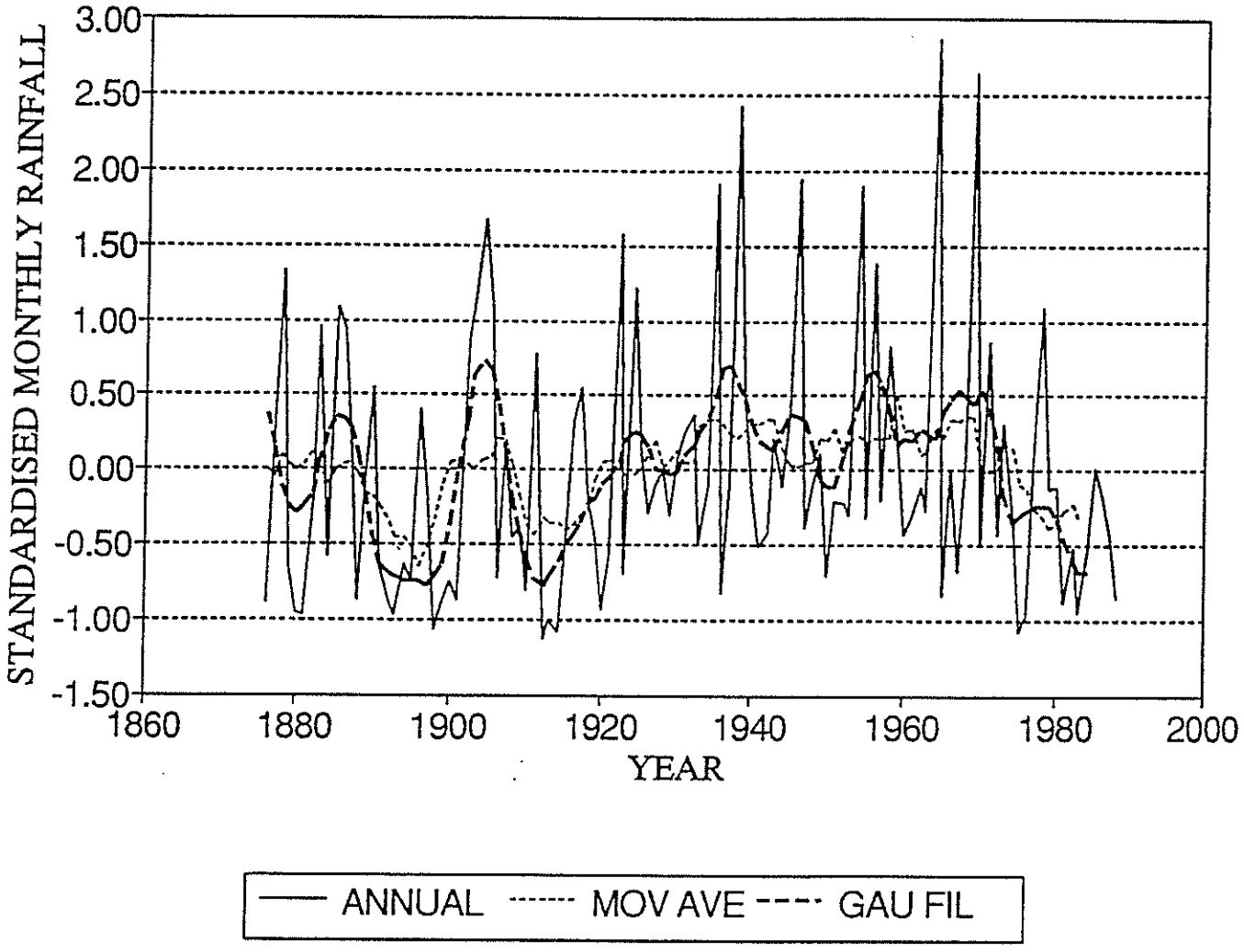


Fig B94 Plot of February rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

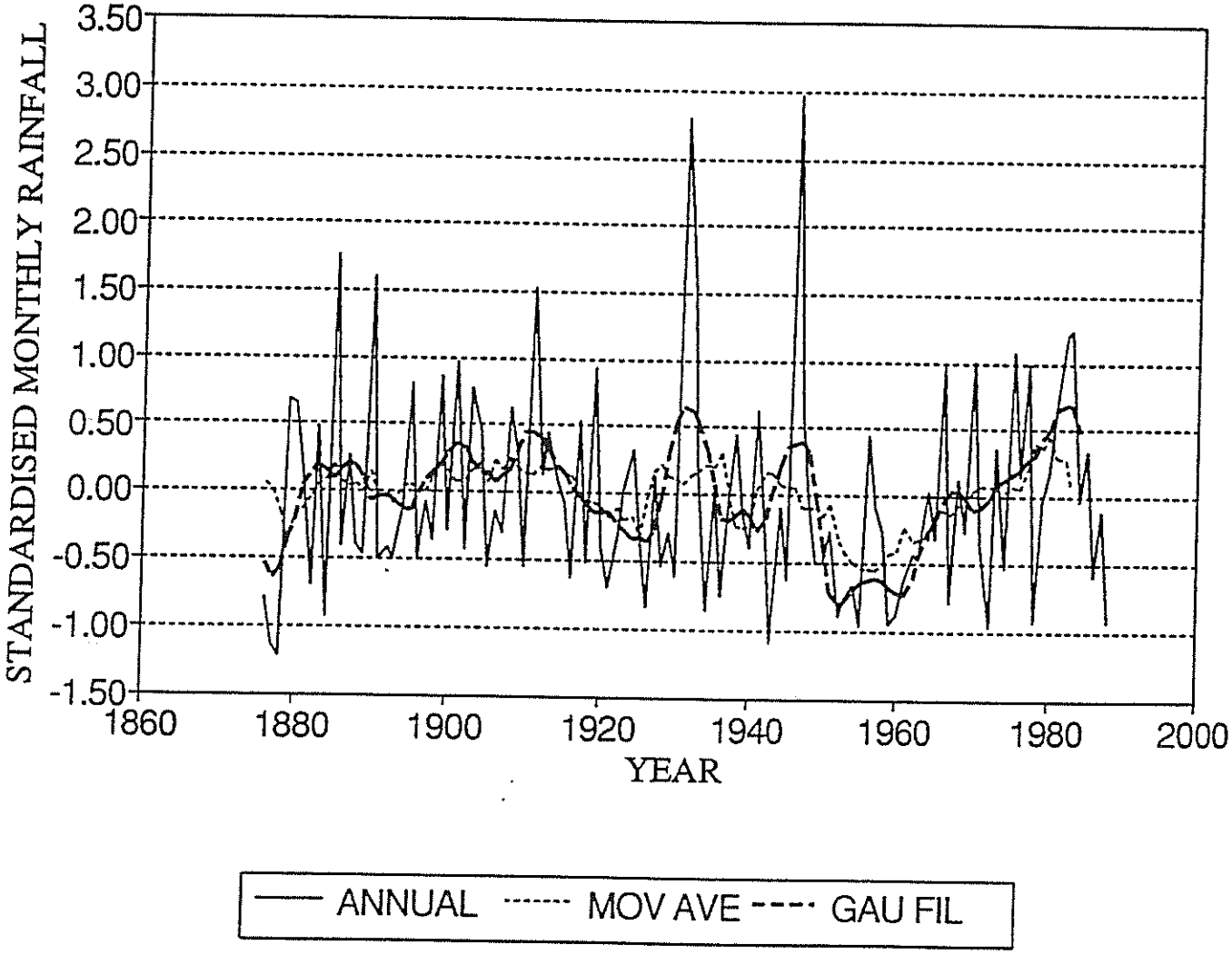


Fig B95 Plot of March rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

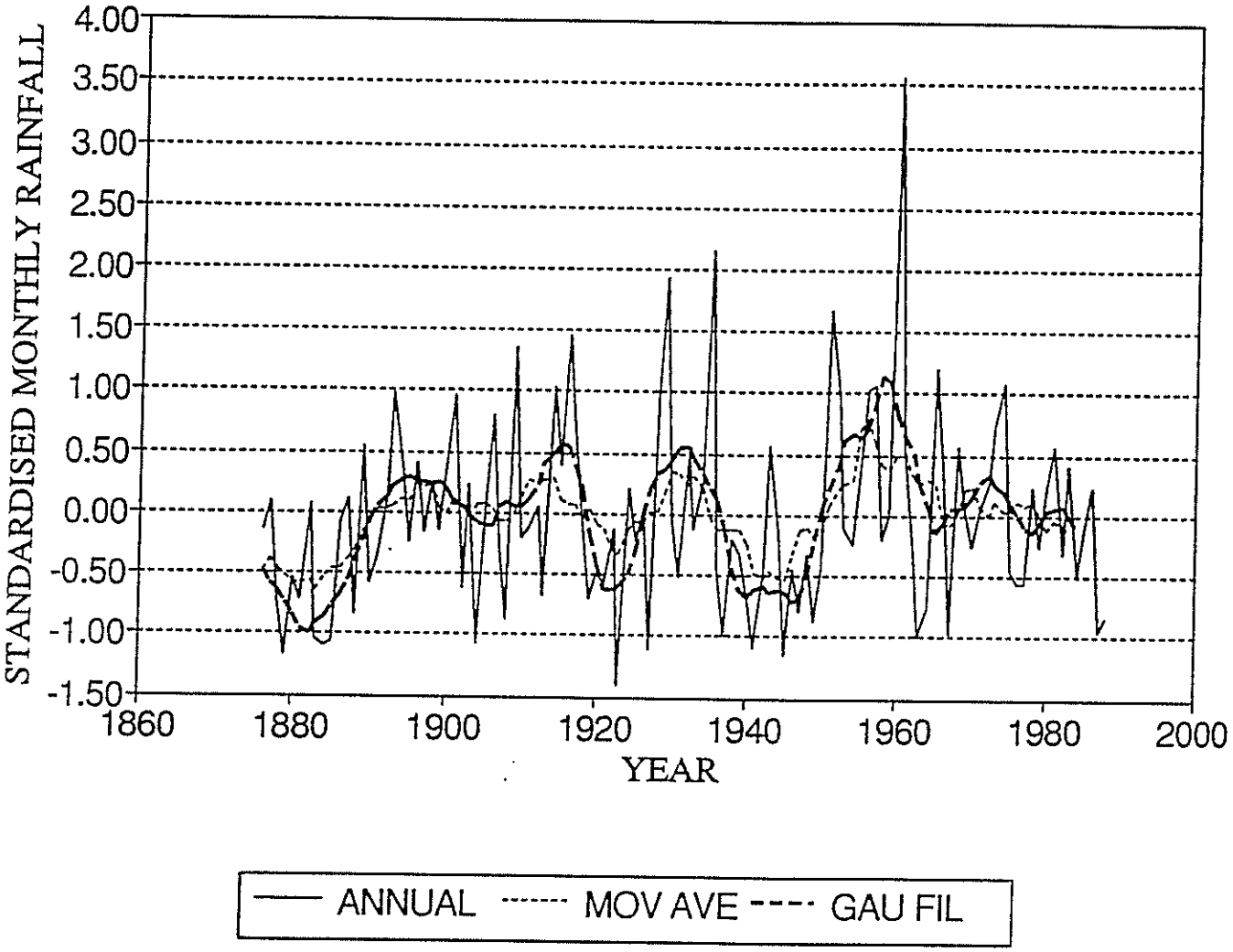


Fig B96 Plot of April rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

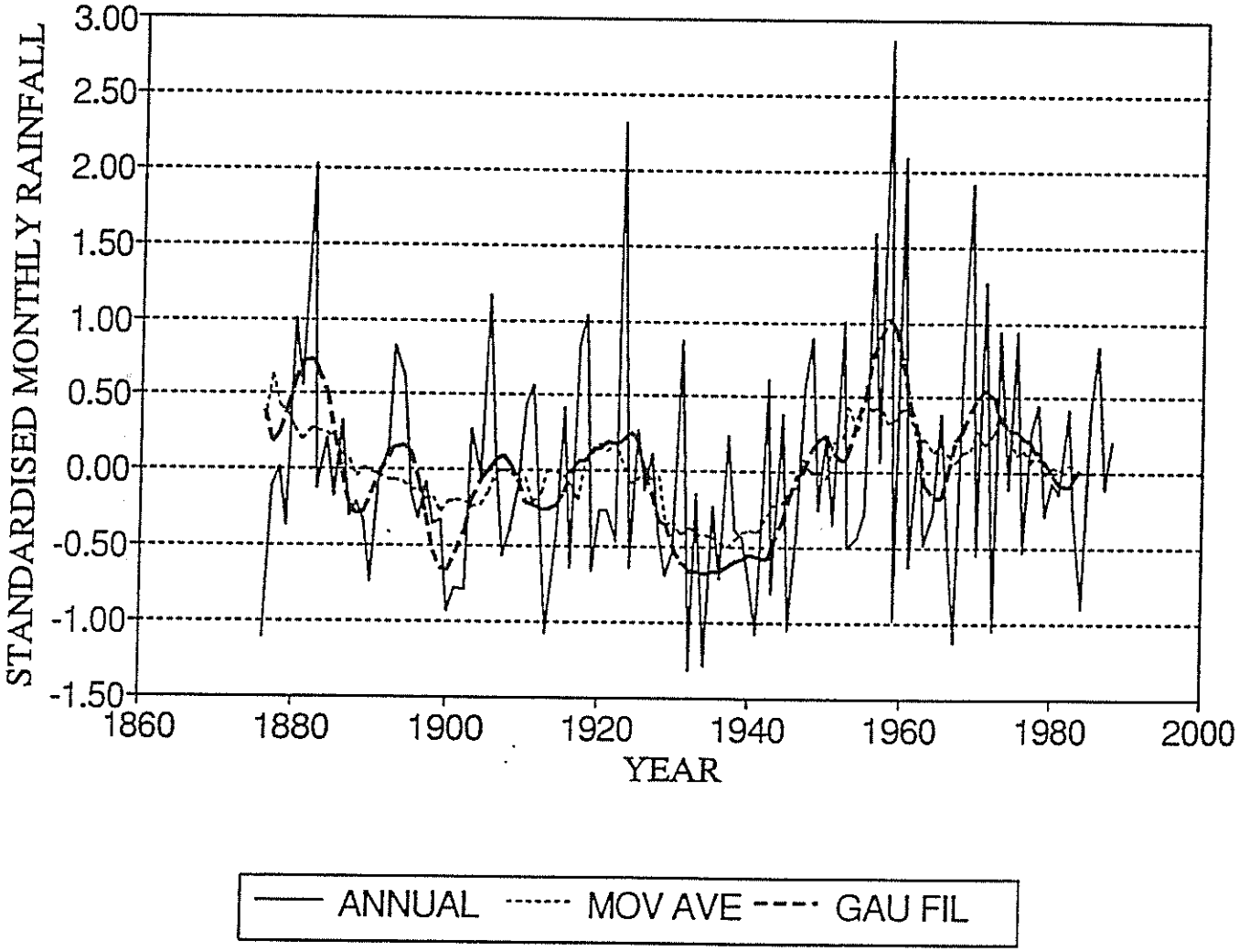


Fig B97 Plot of May rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

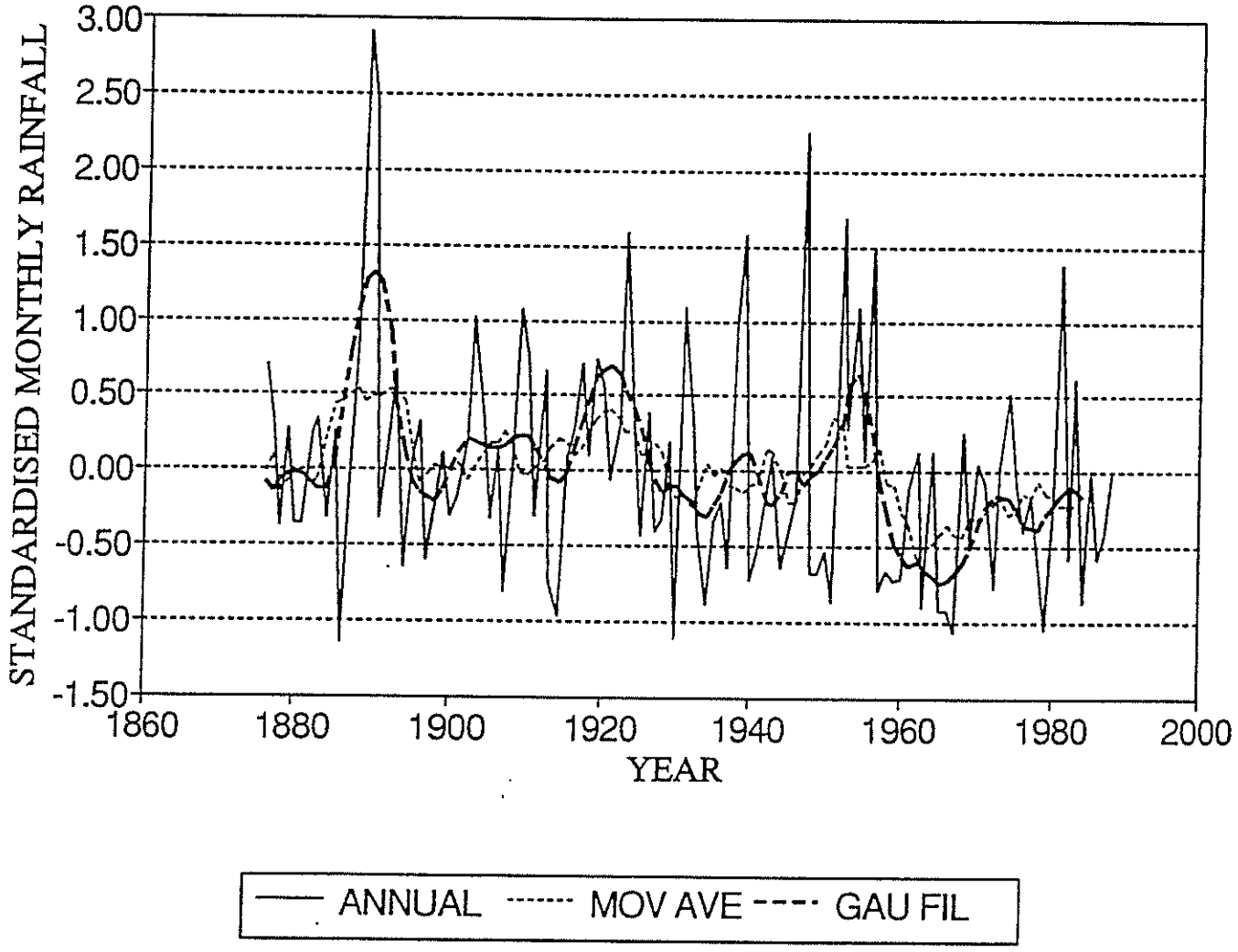


Fig B98 Plot of June rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

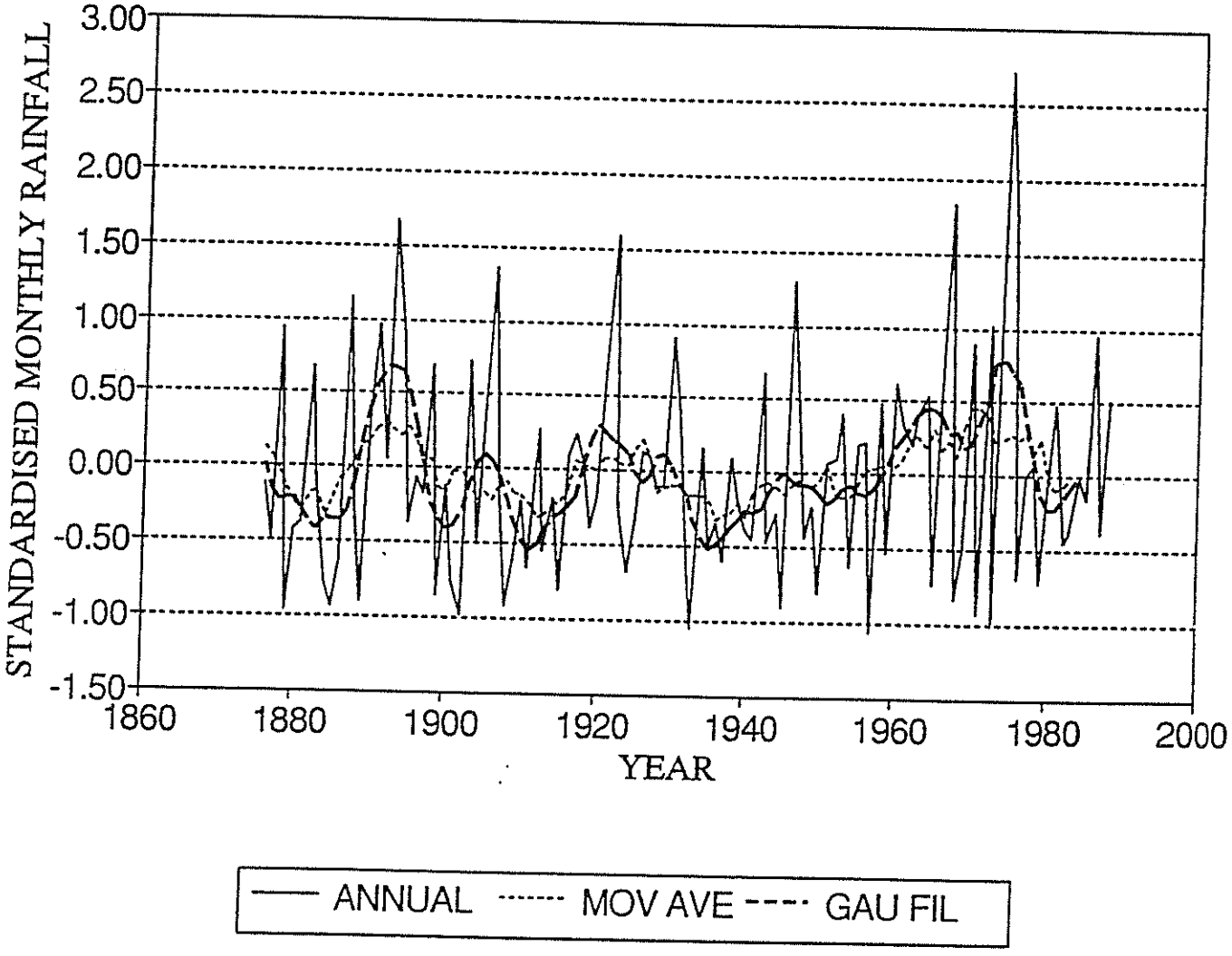


Fig B99 Plot of July rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

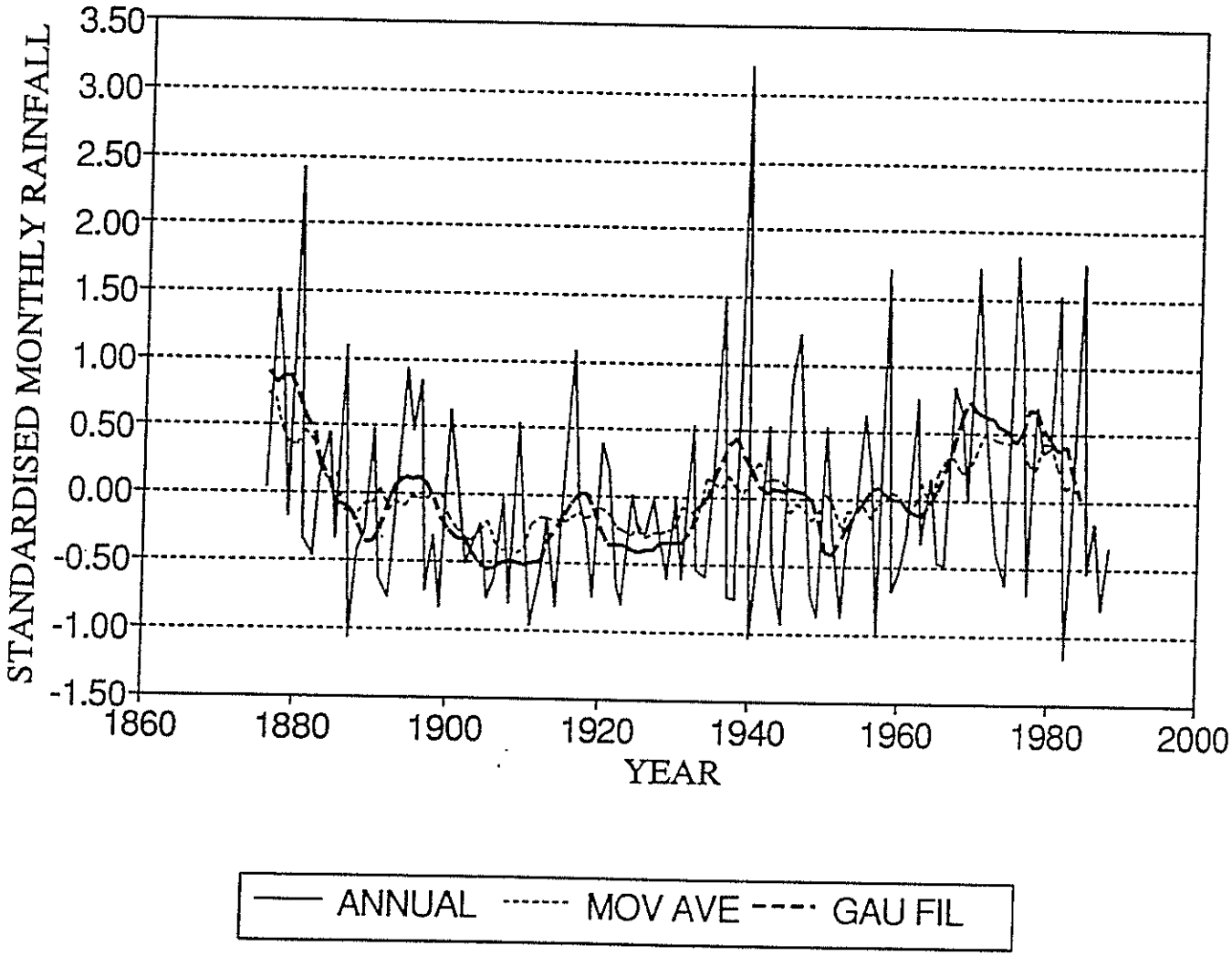


Fig B100 Plot of August rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

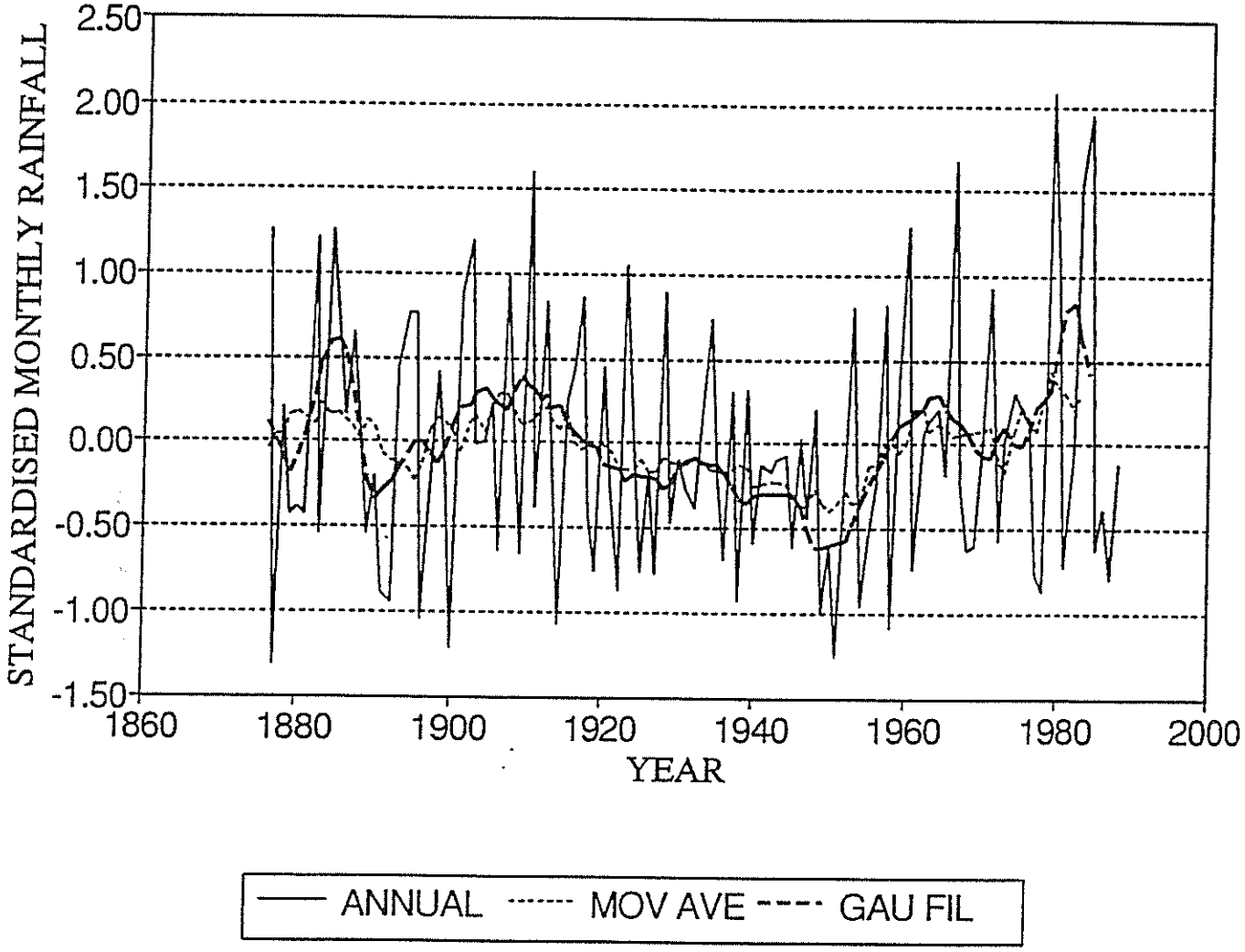


Fig B101 Plot of September rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

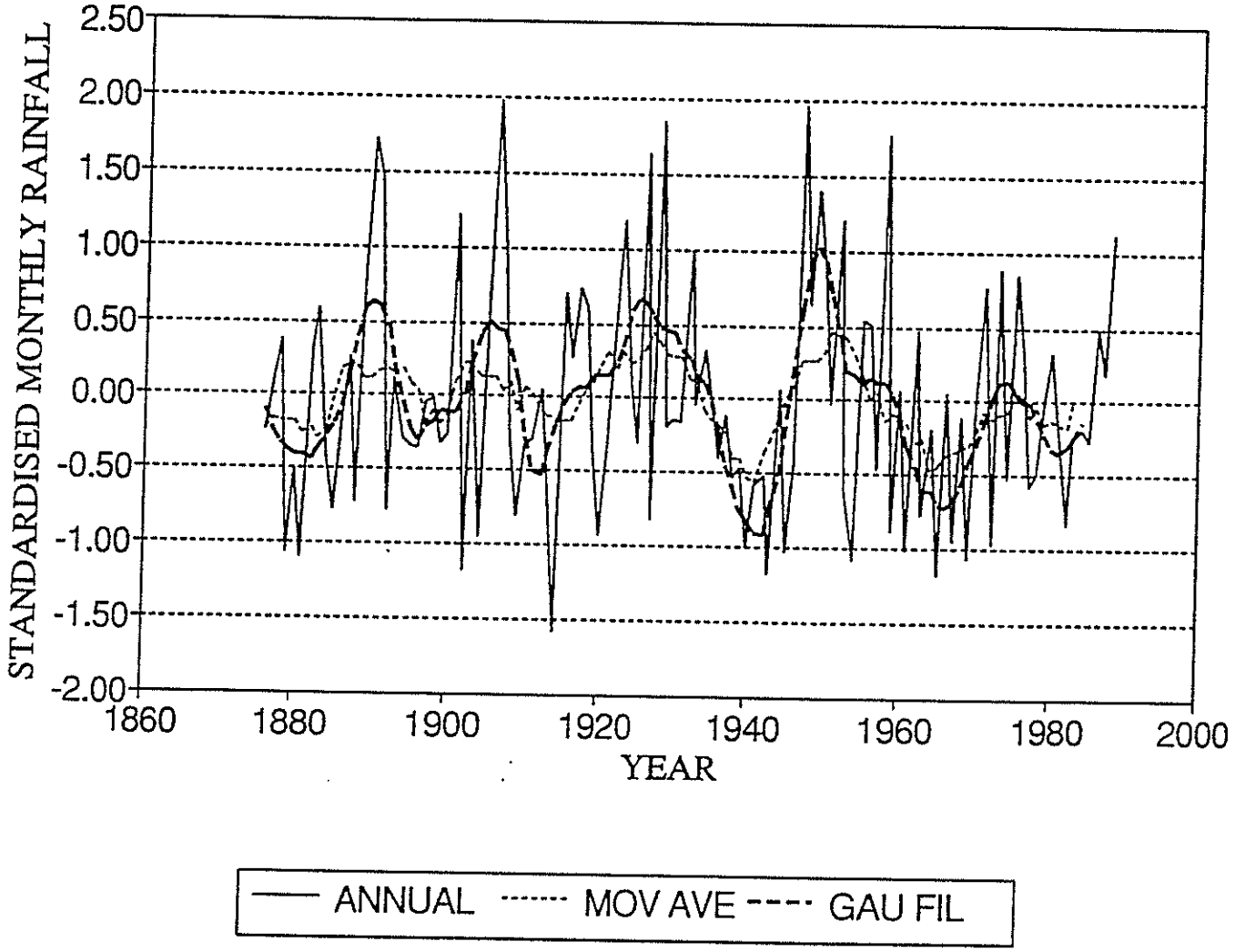


Fig B102 Plot of October rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

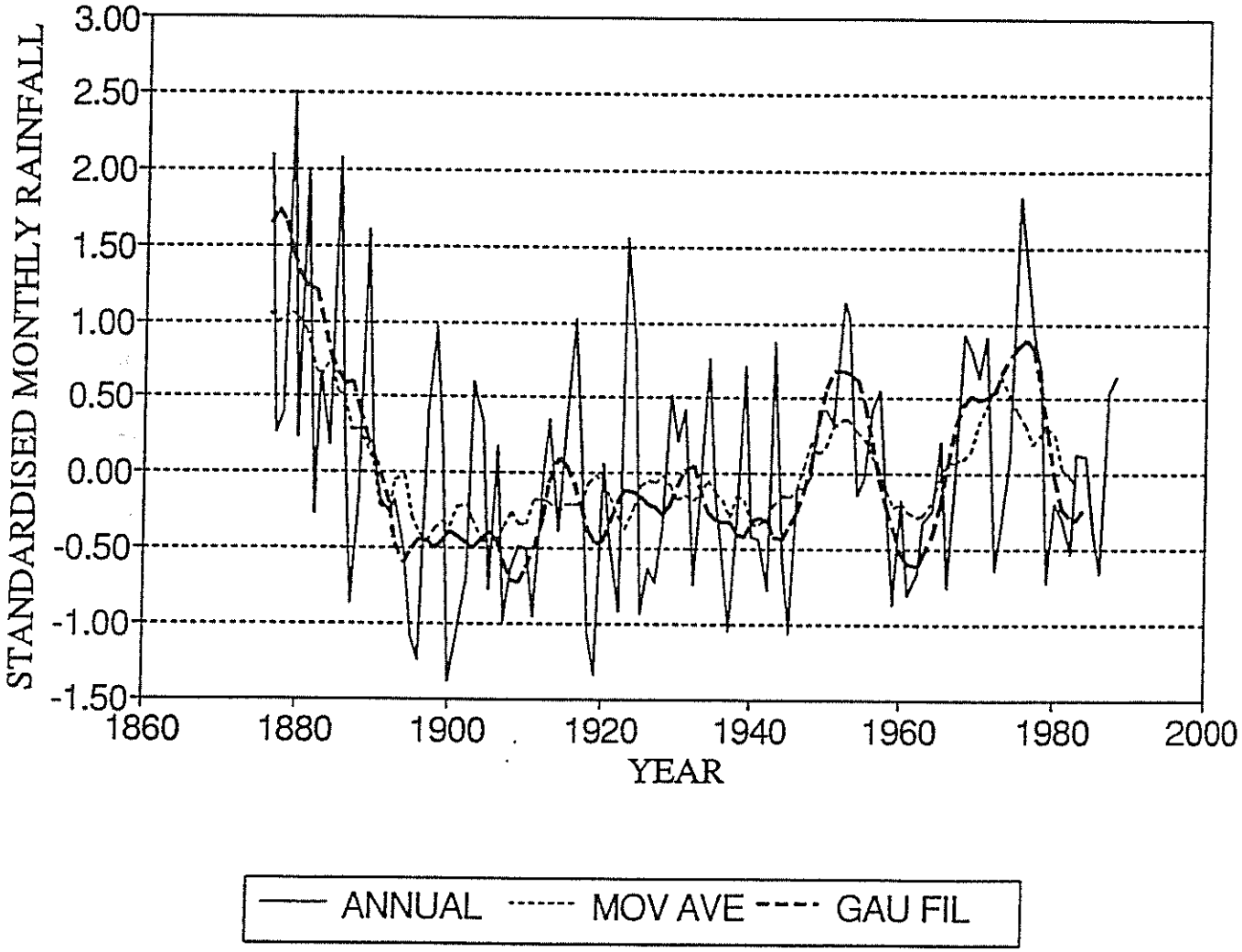


Fig B103 Plot of November rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

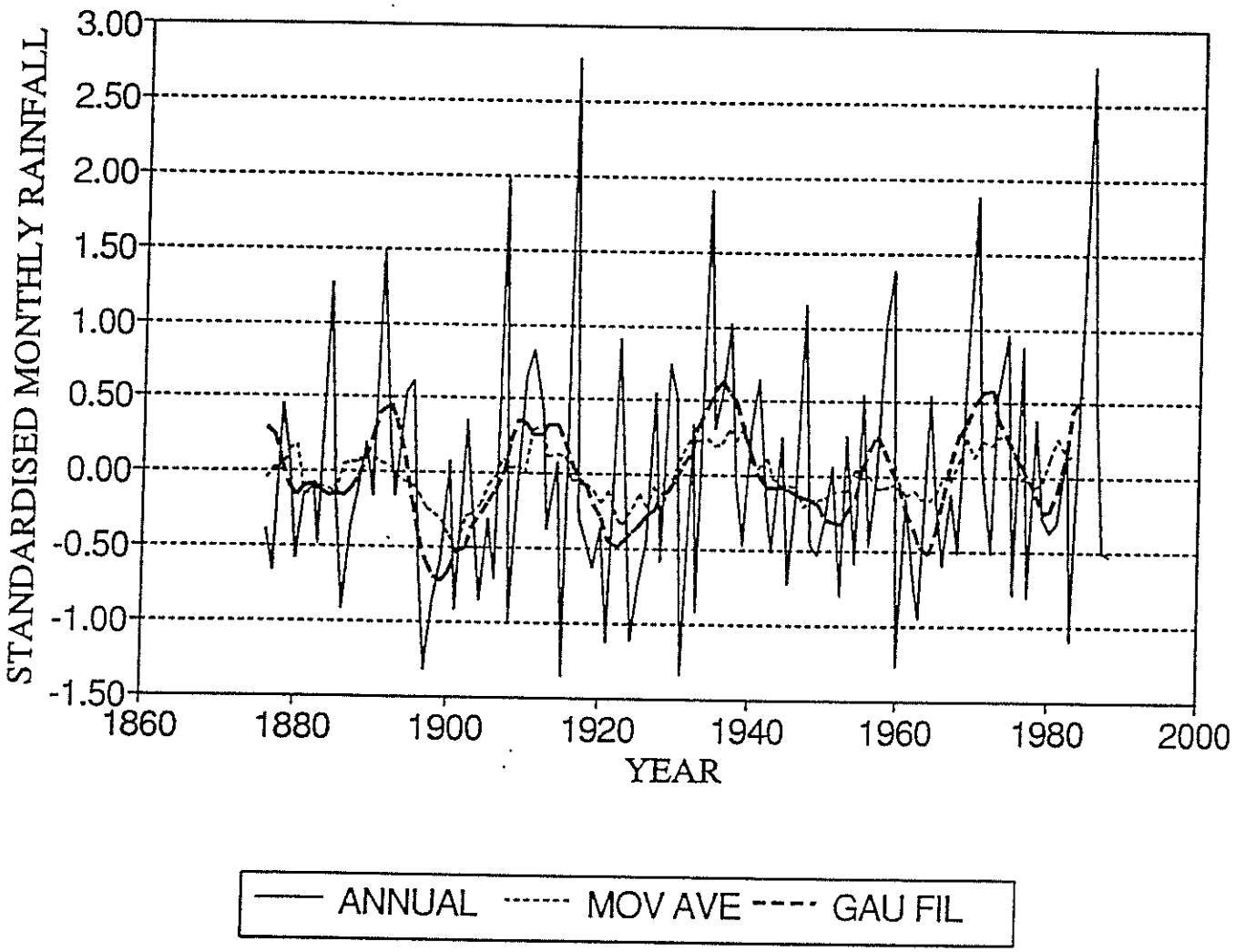


Fig B104 Plot of December rainfall time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

APPENDIX - C

FIGURES FOR THE ANALYSIS OF RAINDAY DATA

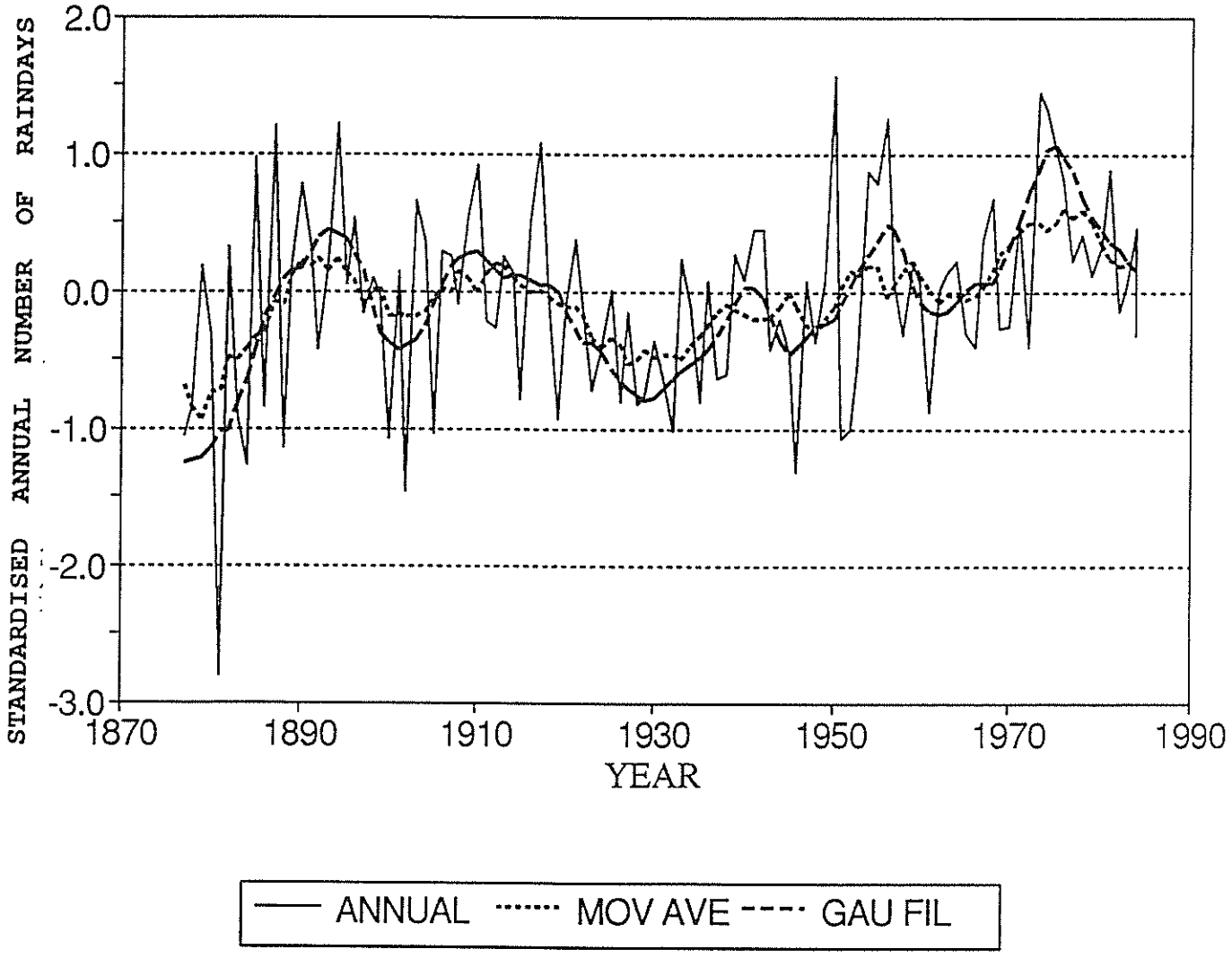


Fig C1. Plot of annual raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - tropical region.

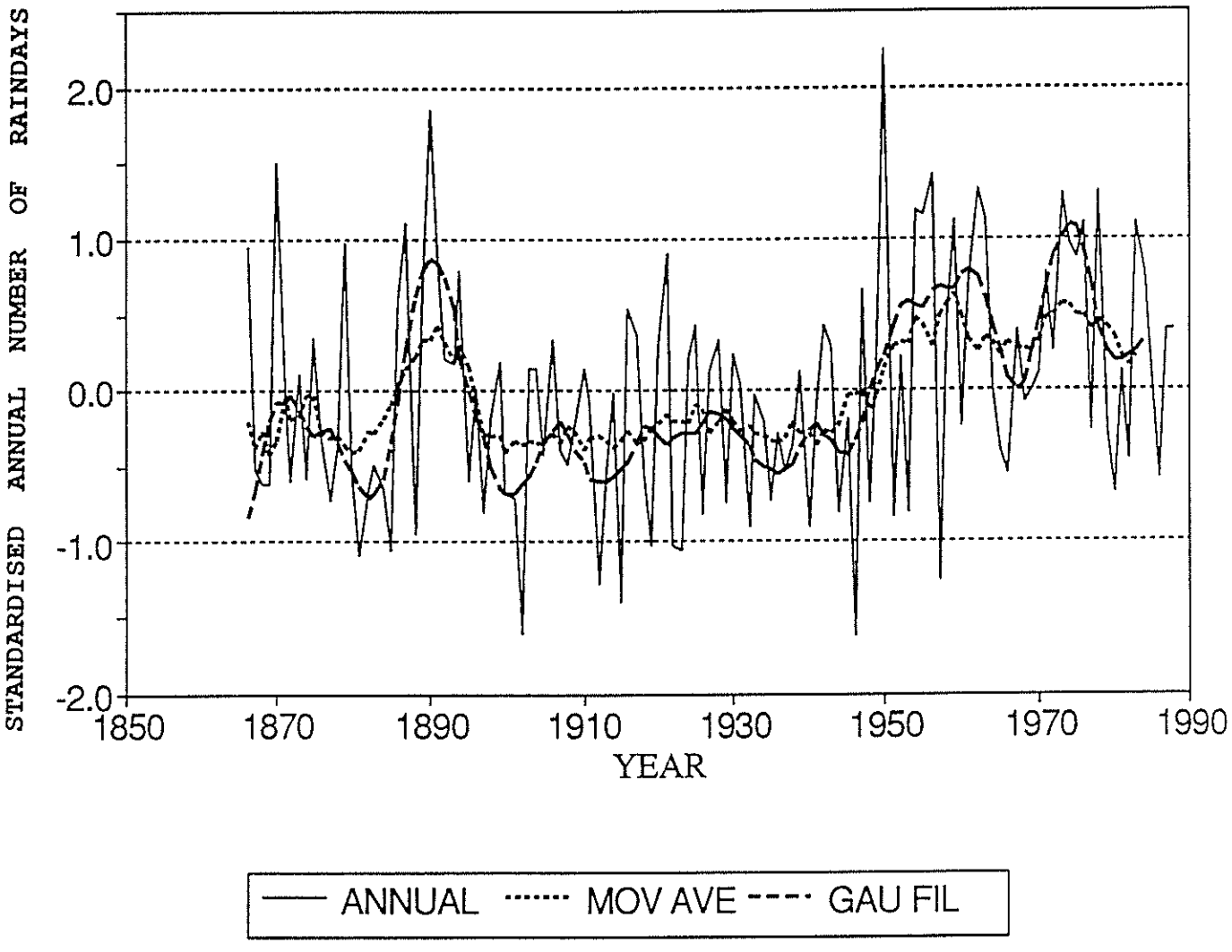


Fig C2. Plot of annual raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - subtropical region.

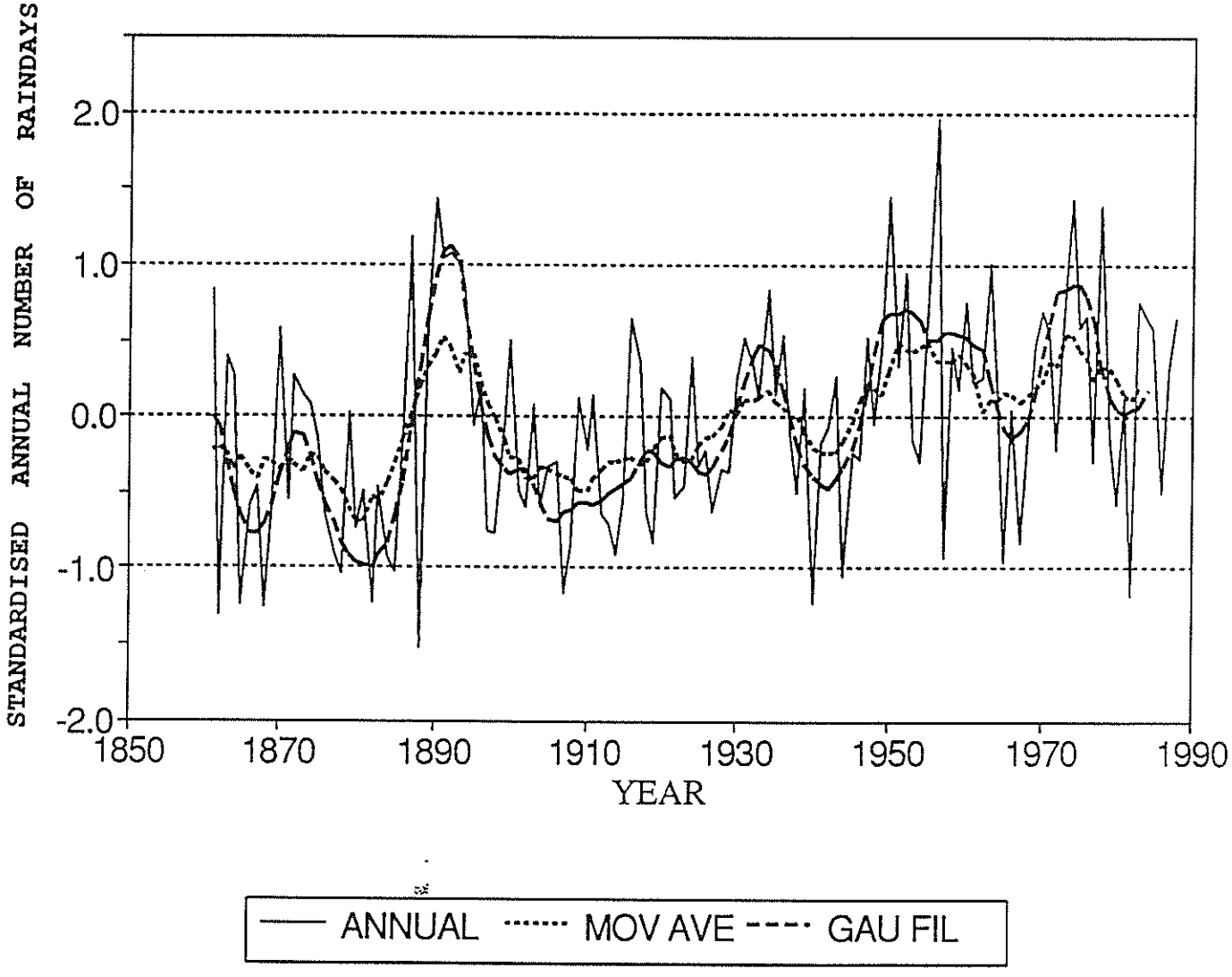


Fig C3. Plot of annual raindays time series with 11 year moving average and 11 point Gaussian filter for uniform rainfall - temperate region.

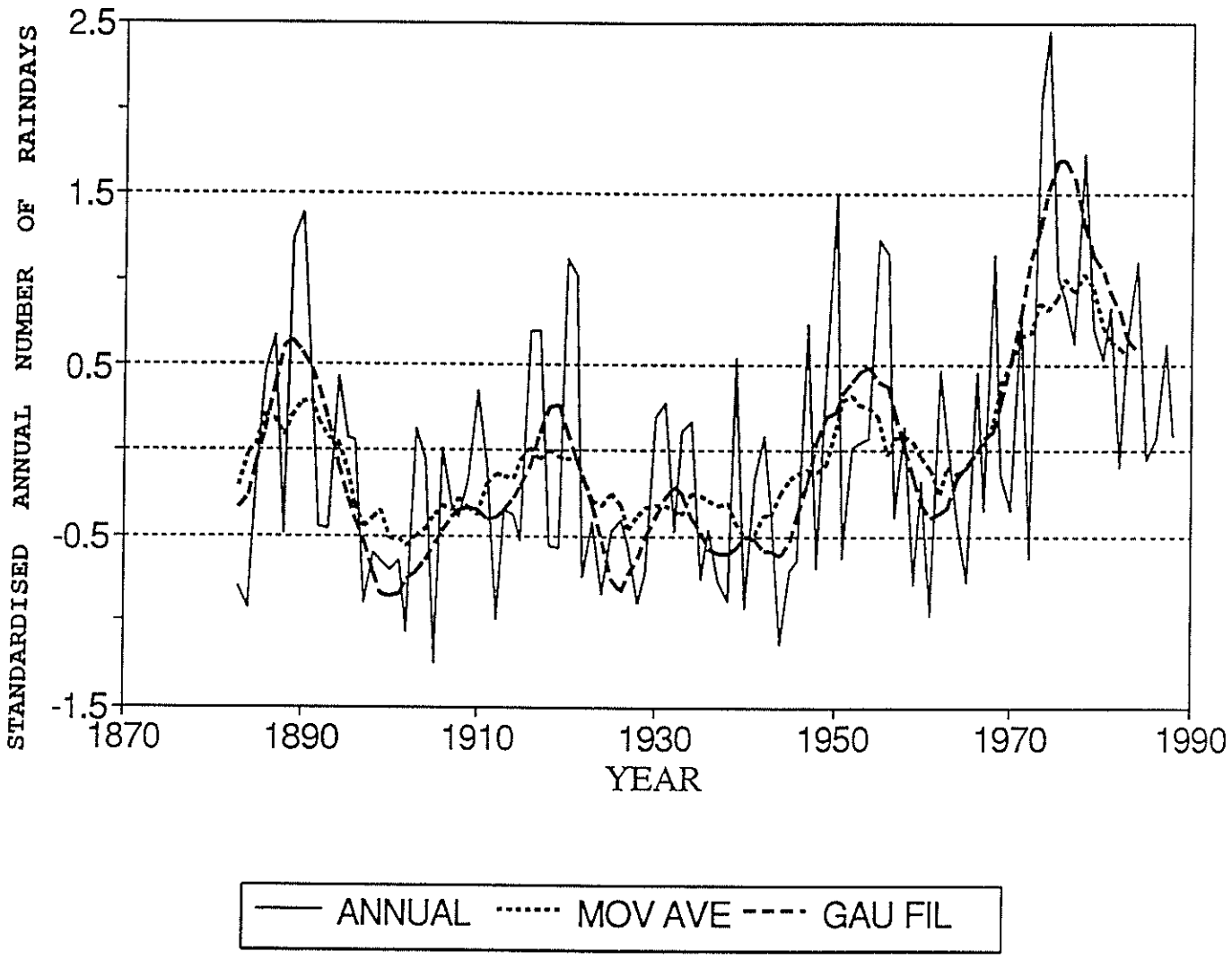


Fig C4.Plot of annual raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - arid region.

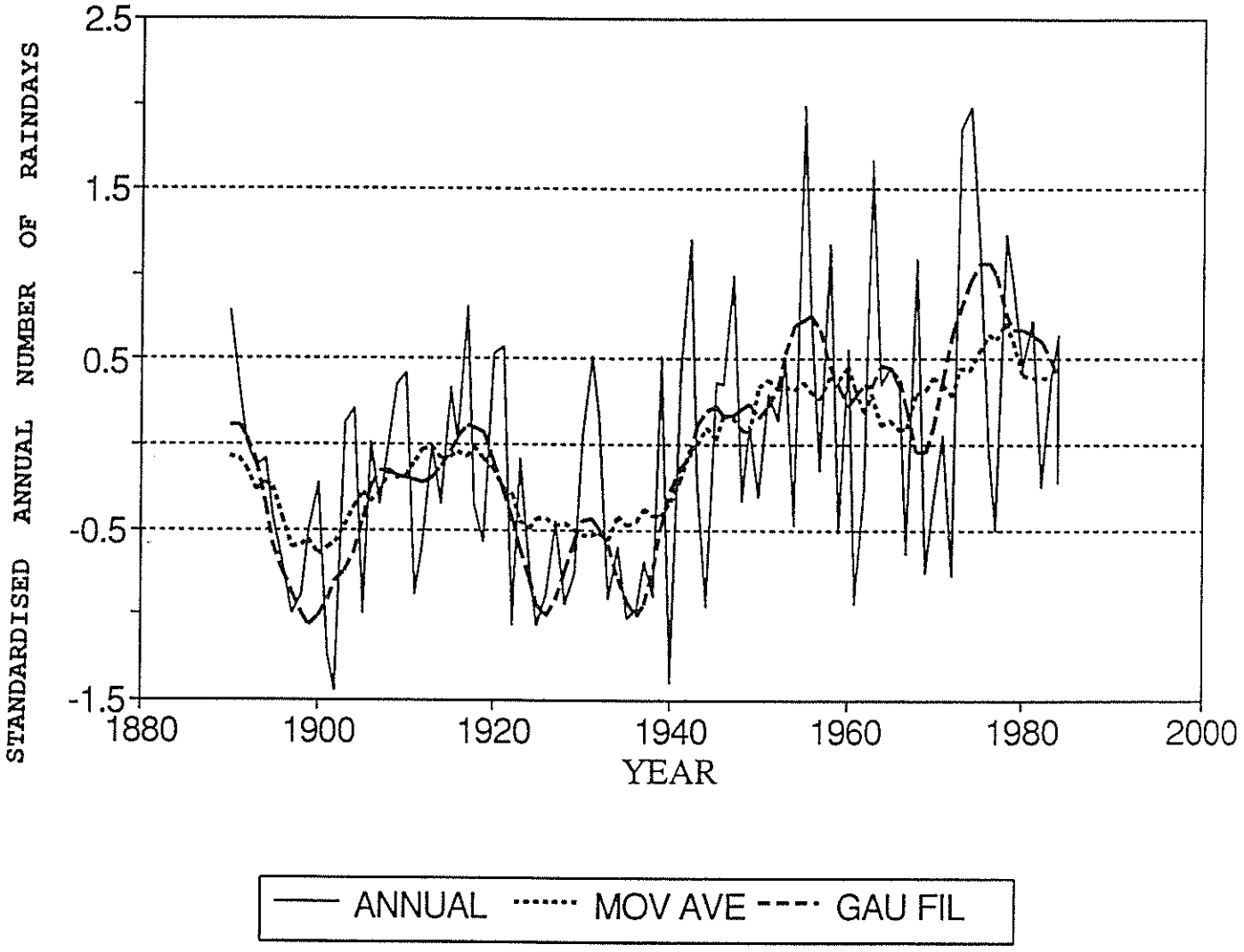


Fig C5. Plot of annual raindays time series with 11 year moving average and 11 point Gaussian filter for winter/non-seasonal rainfall - arid region.

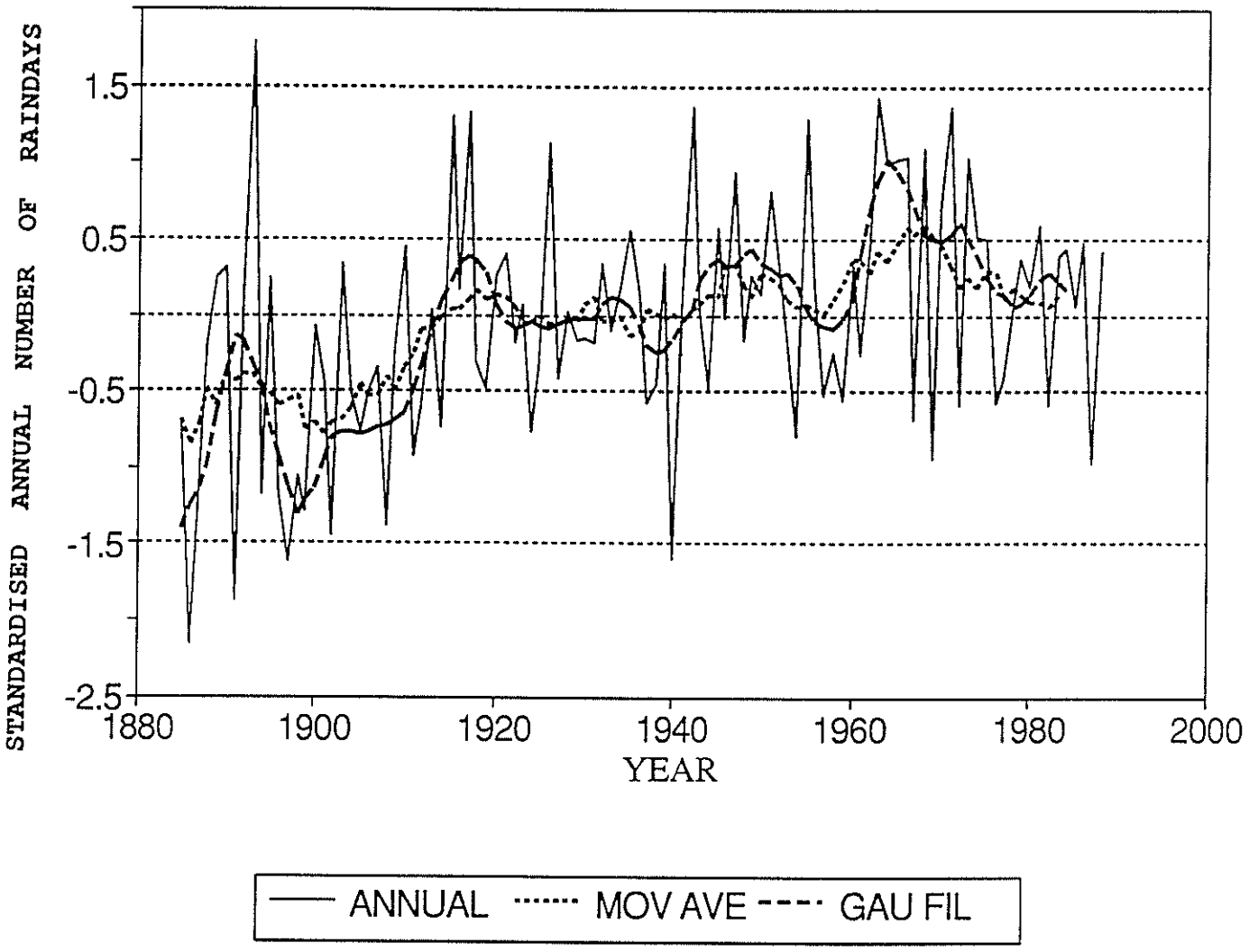


Fig C6. Plot of annual raindays time series with 11 year moving average and 11 point Gaussian filter for winter rainfall - temperate region.

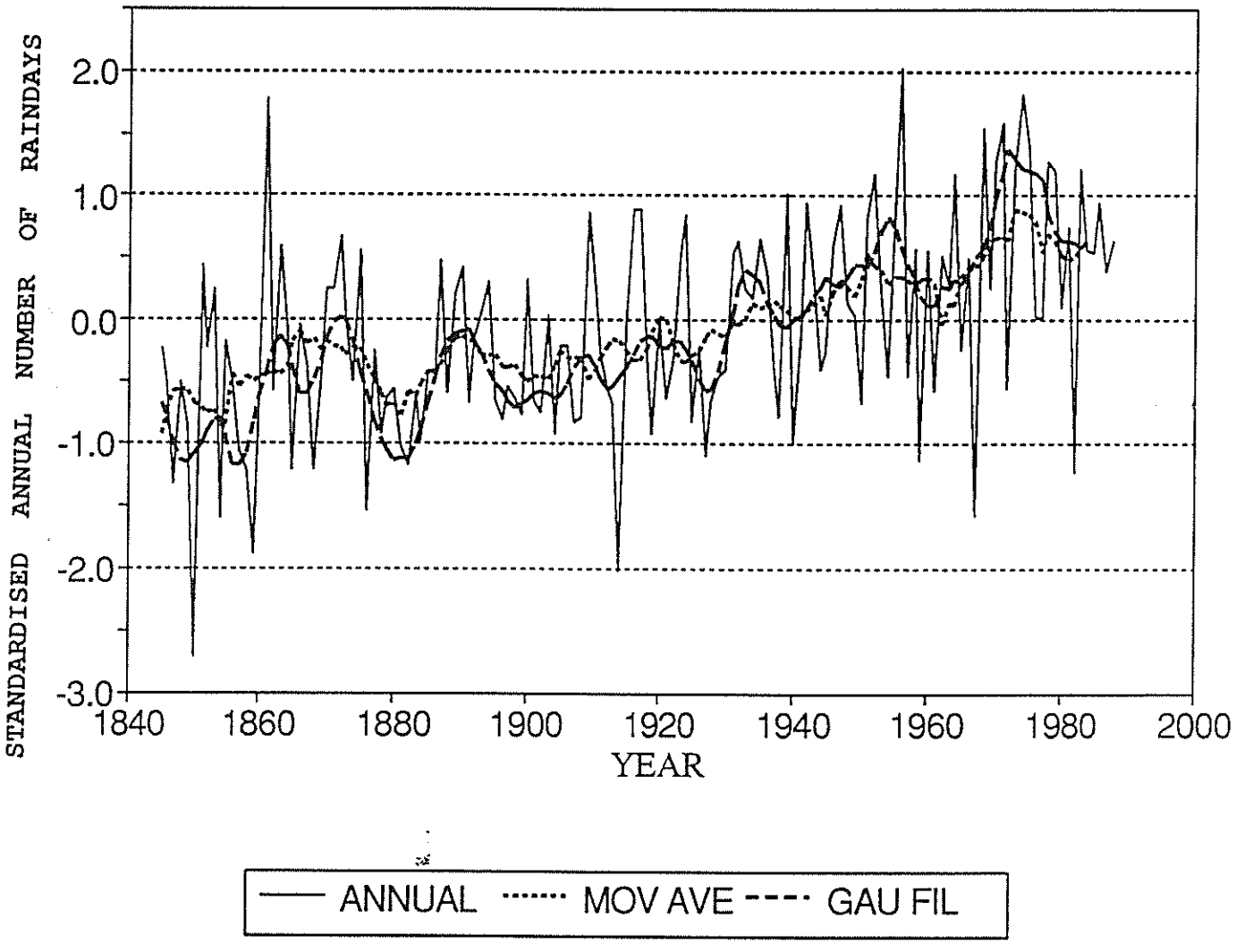


Fig C7. Plot of annual raindays time series with 11 year moving average and 11 point Gaussian filter for winter rainfall - temperate region.

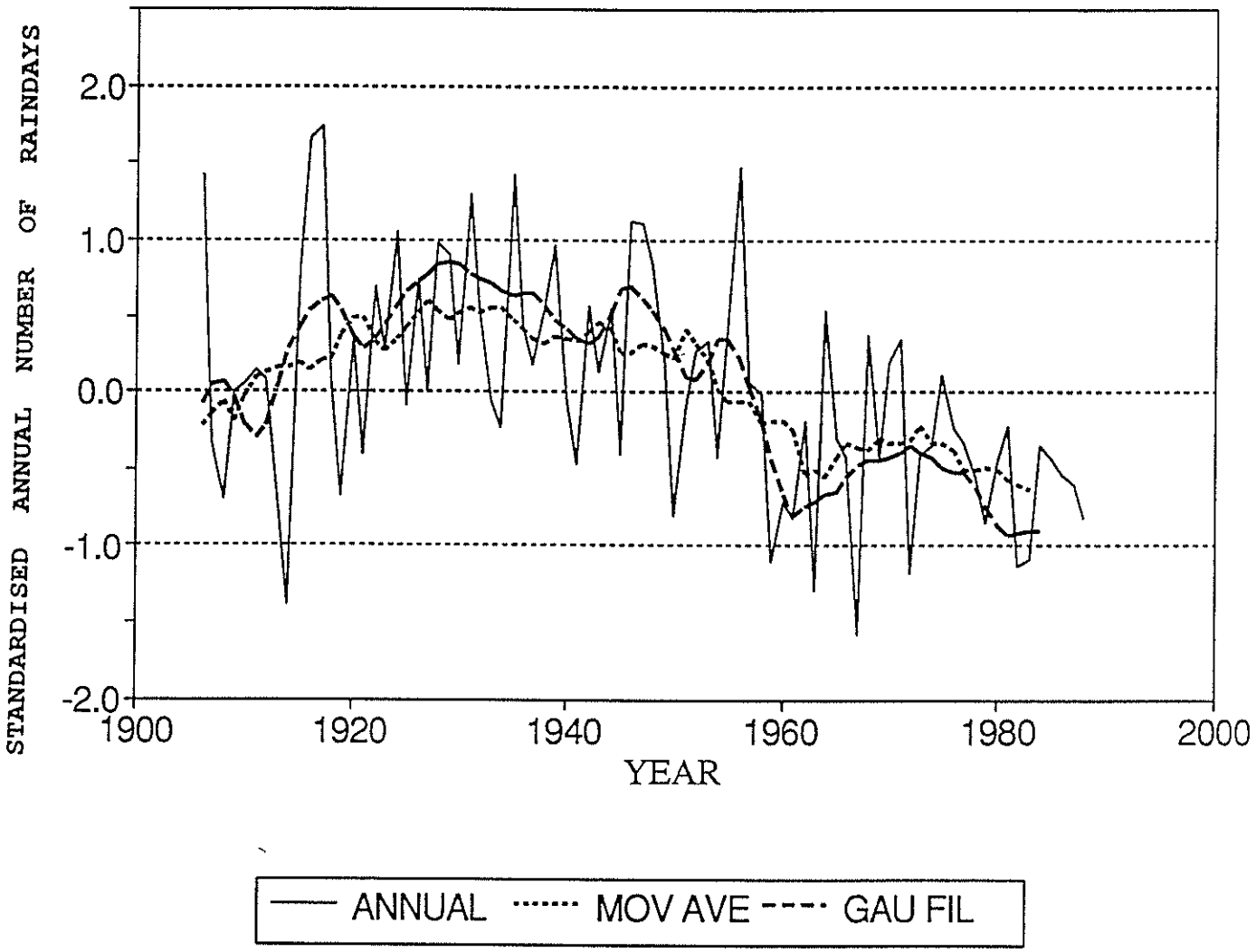


Fig C8. Plot of annual raindays time series with 11 year moving average and 11 point Gaussian filter for winter rainfall (Tasmania) region.

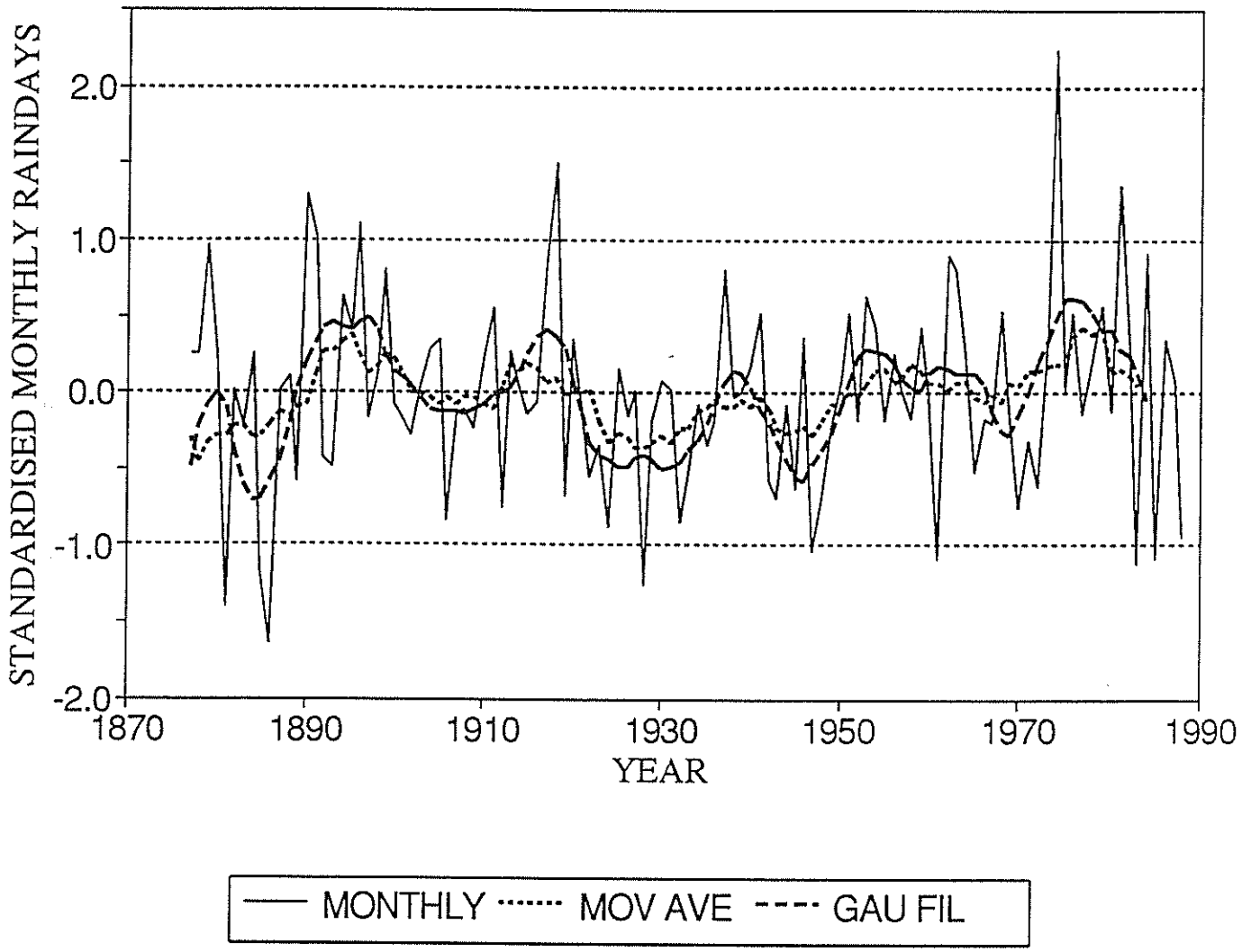


Fig C9. Plot of January raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - tropical region.

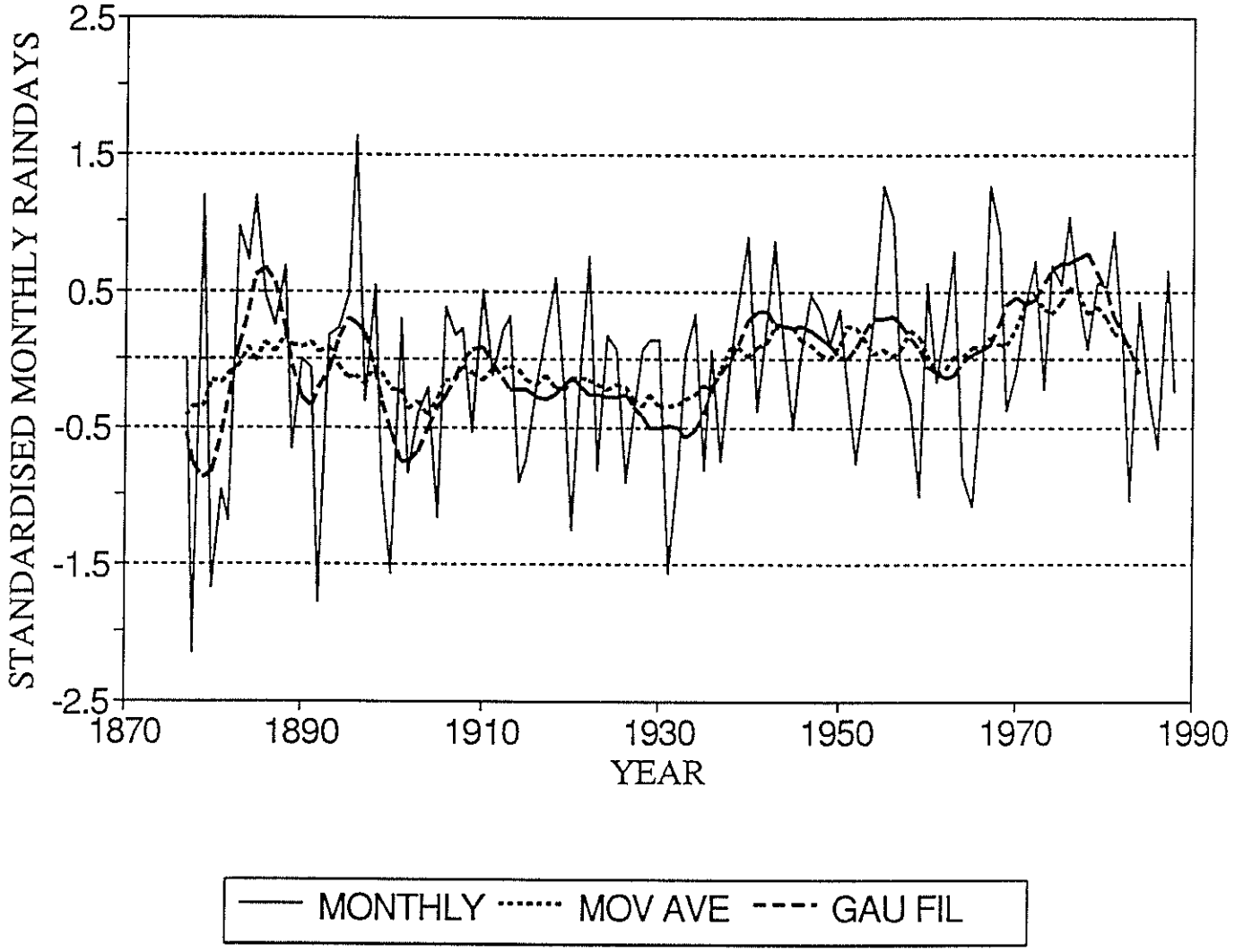


Fig C10. Plot of February raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - tropical region.

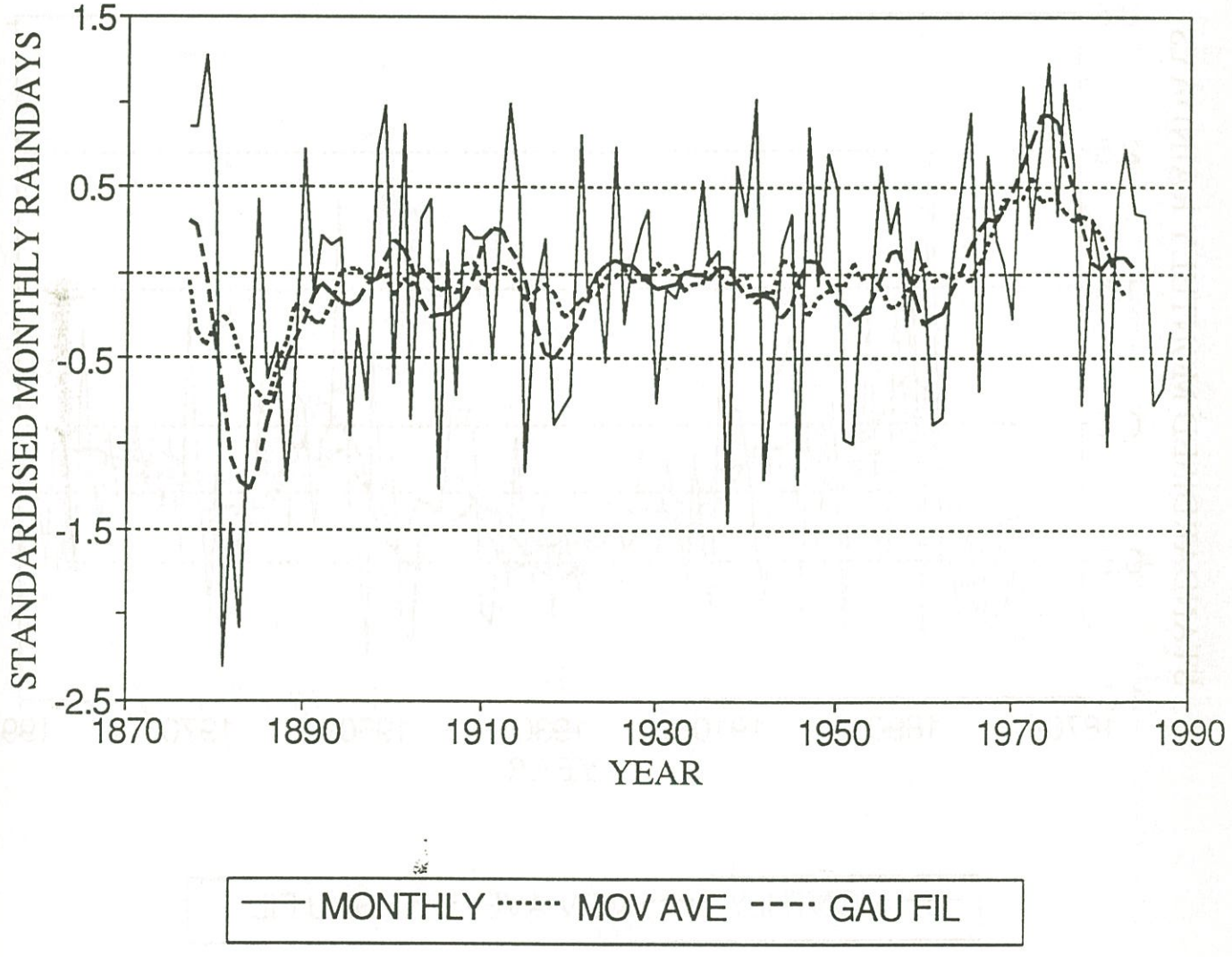


Fig C11. Plot of March raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - tropical region.

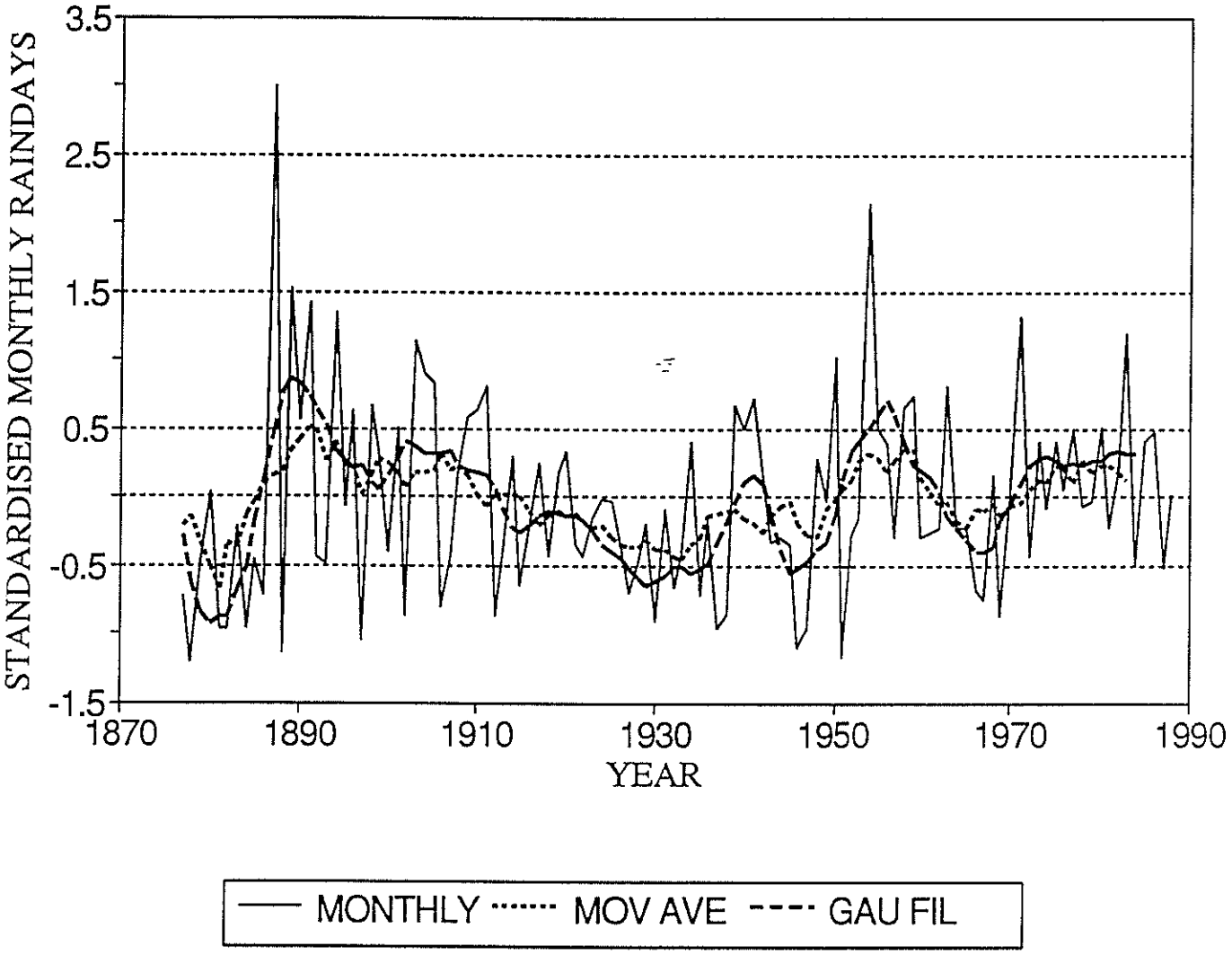


Fig C12. Plot of April raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - tropical region.

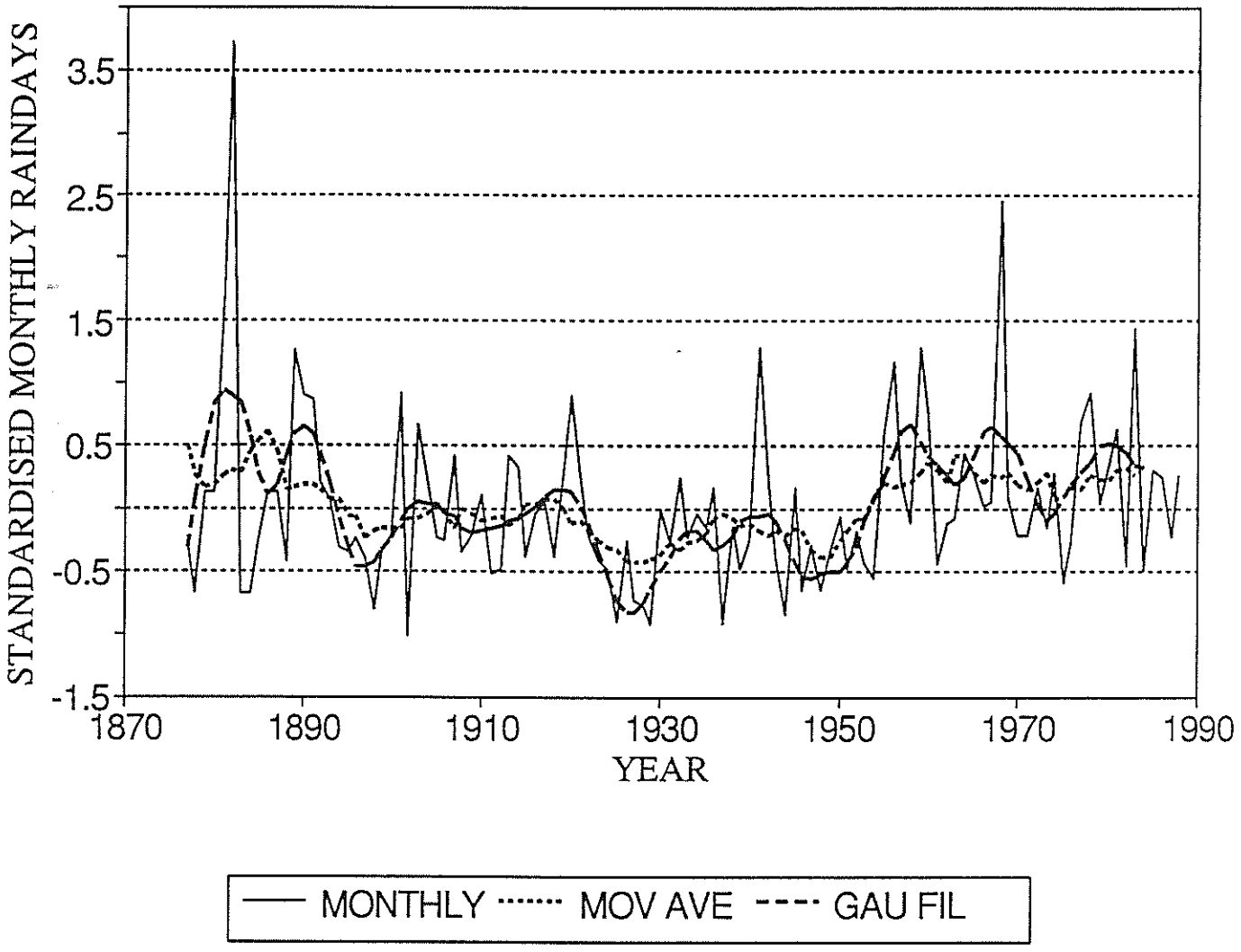


Fig C13. Plot of May raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - tropical region.

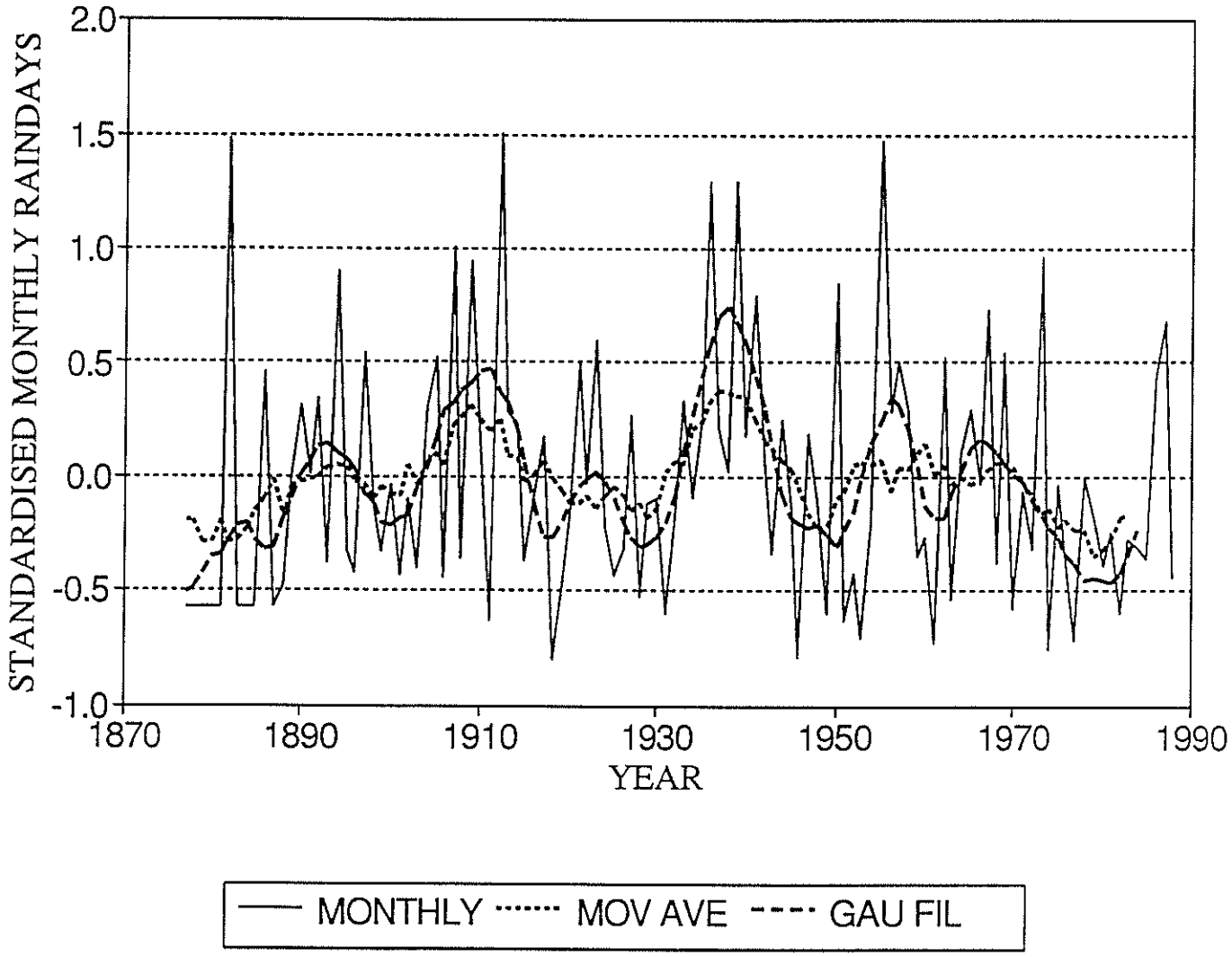


Fig C14. Plot of June raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - tropical region.

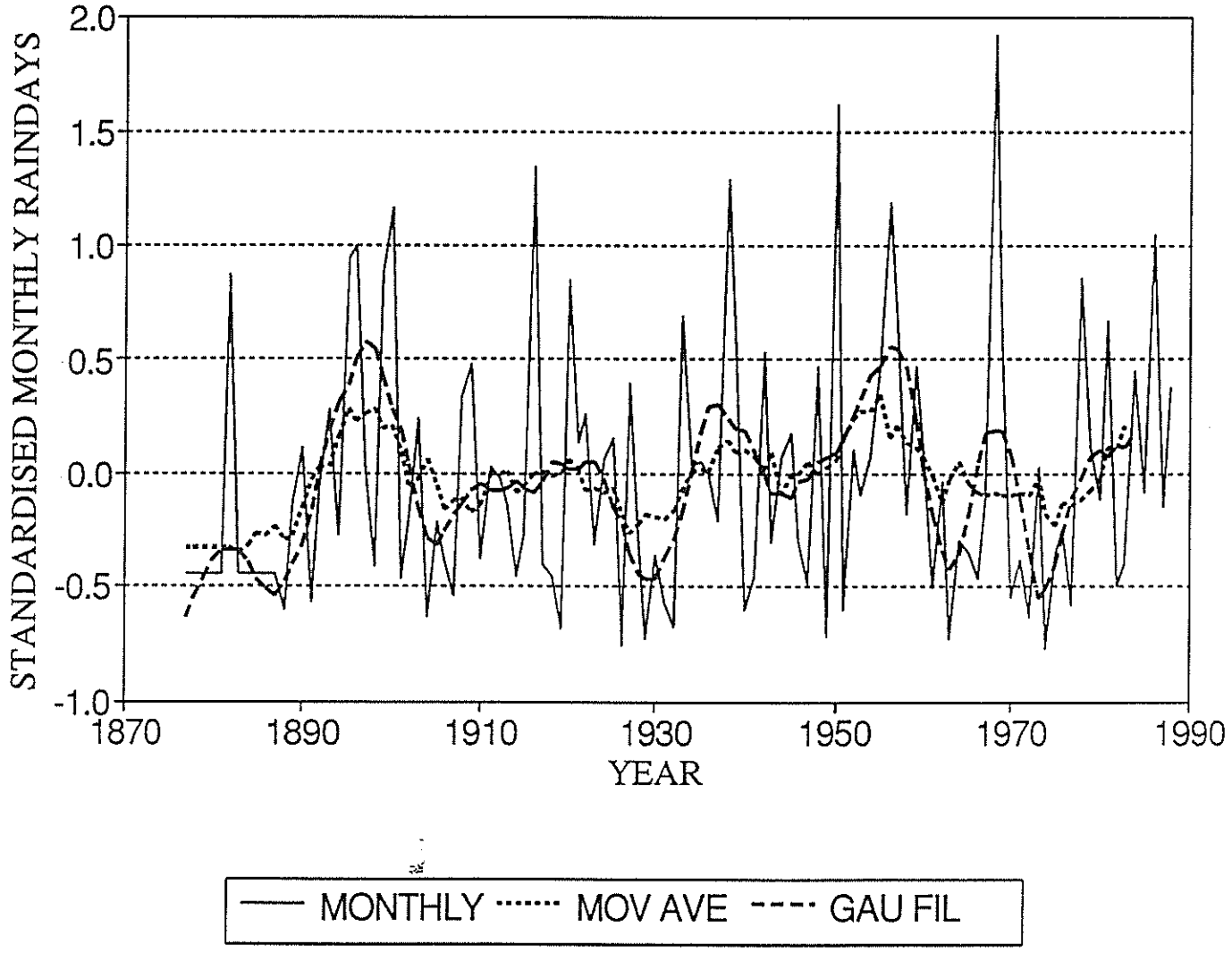


Fig C15. Plot of July raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - tropical region.

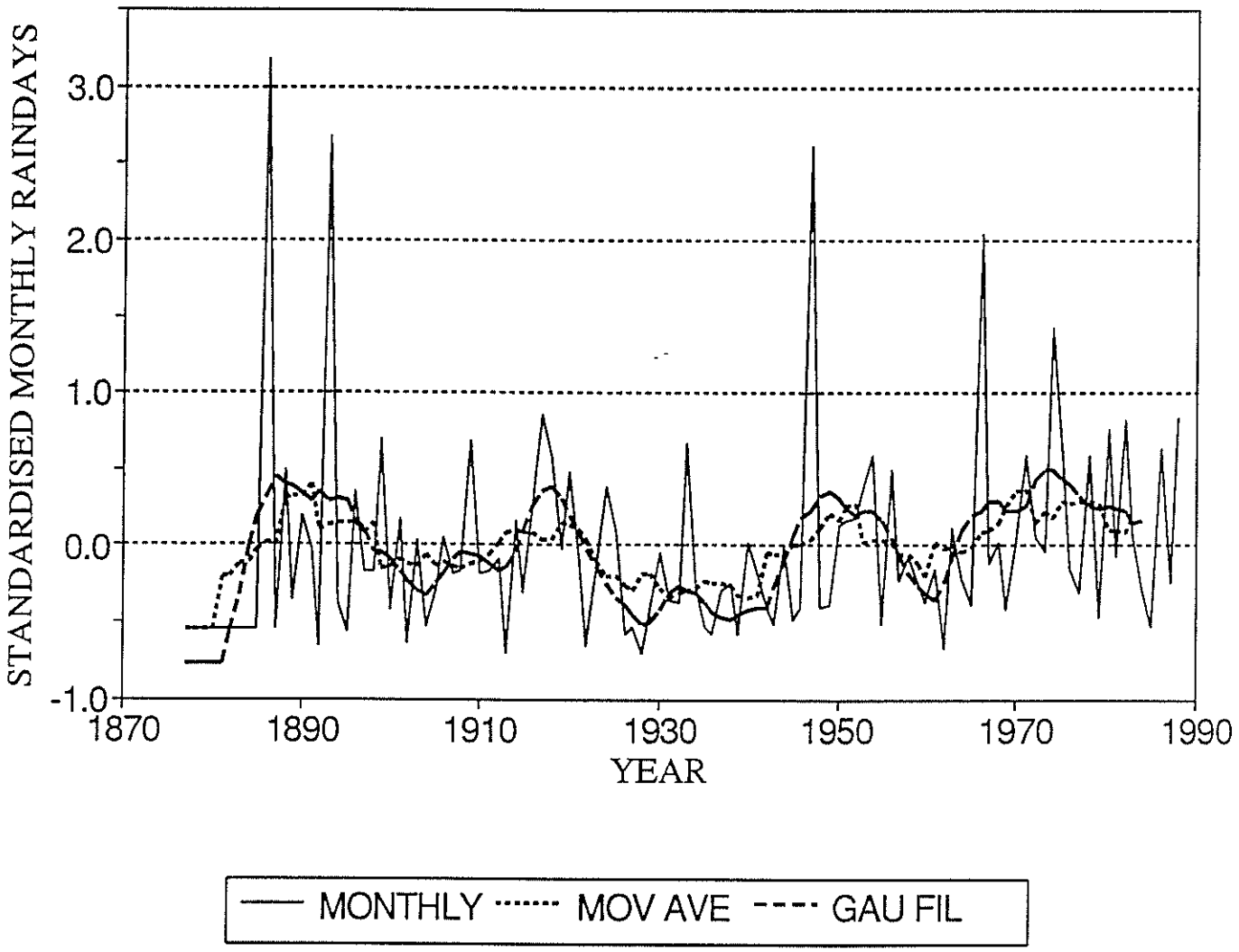


Fig C16. Plot of August raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - tropical region.

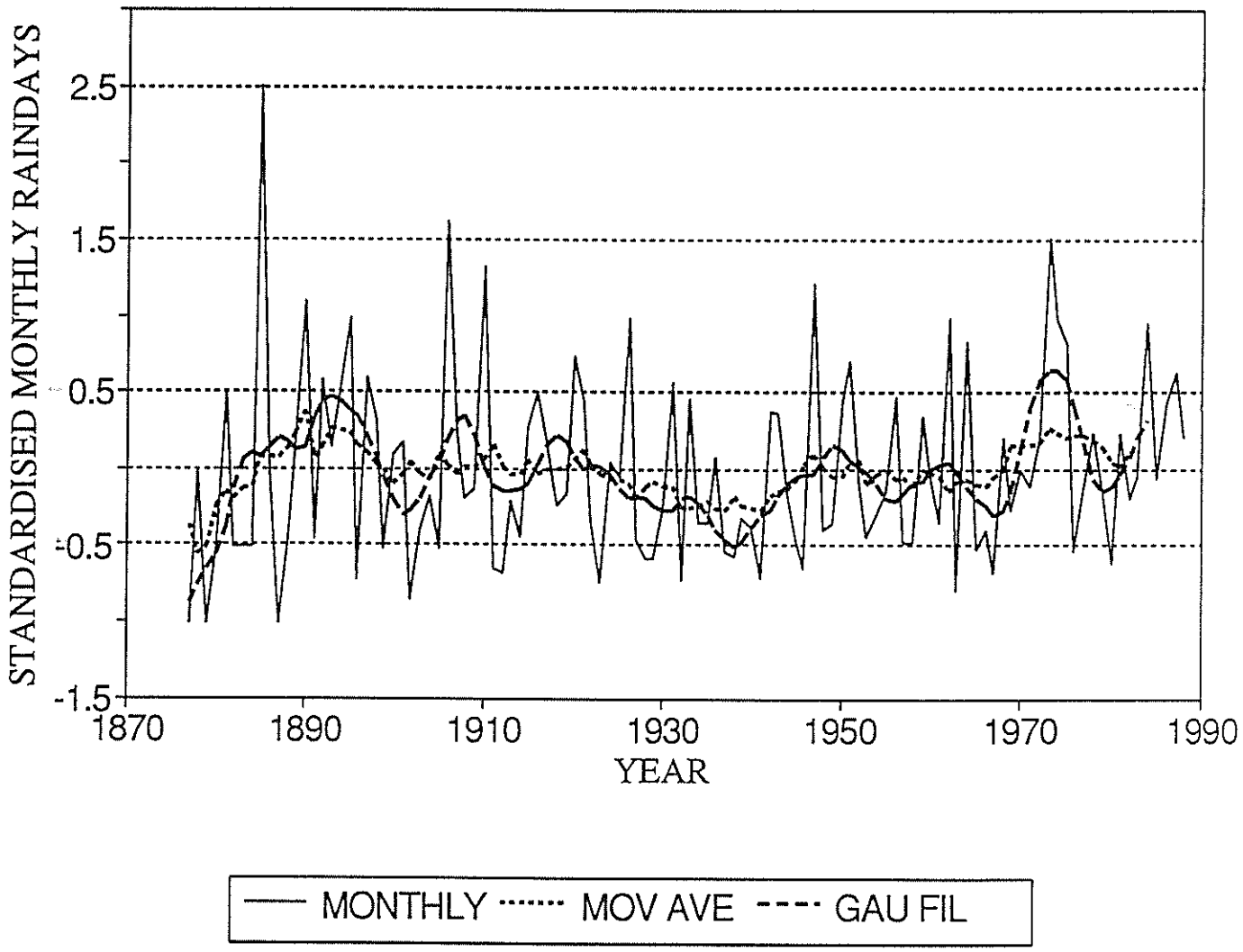


Fig C17. Plot of September raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - tropical region.

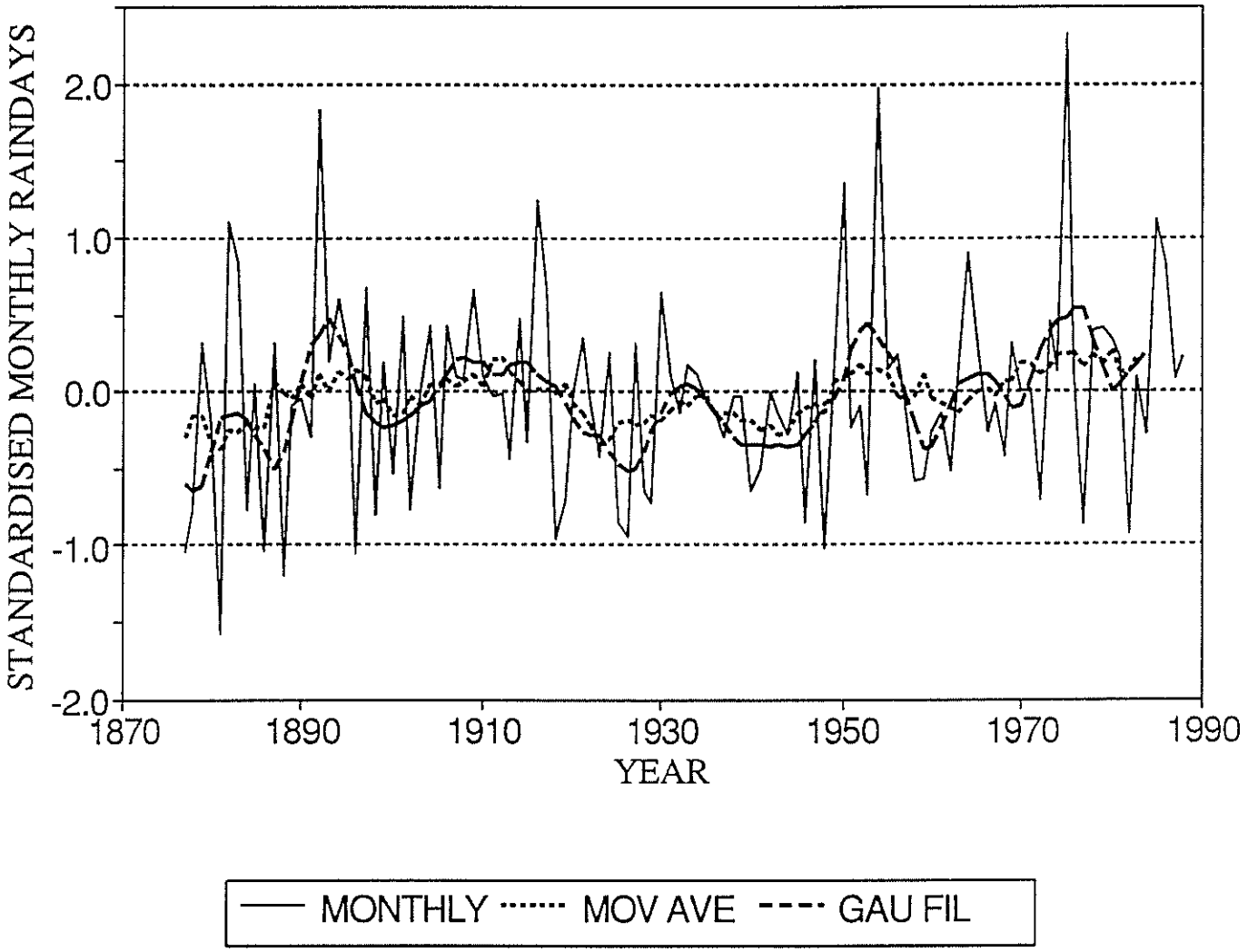


Fig C18. Plot of October raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - tropical region.

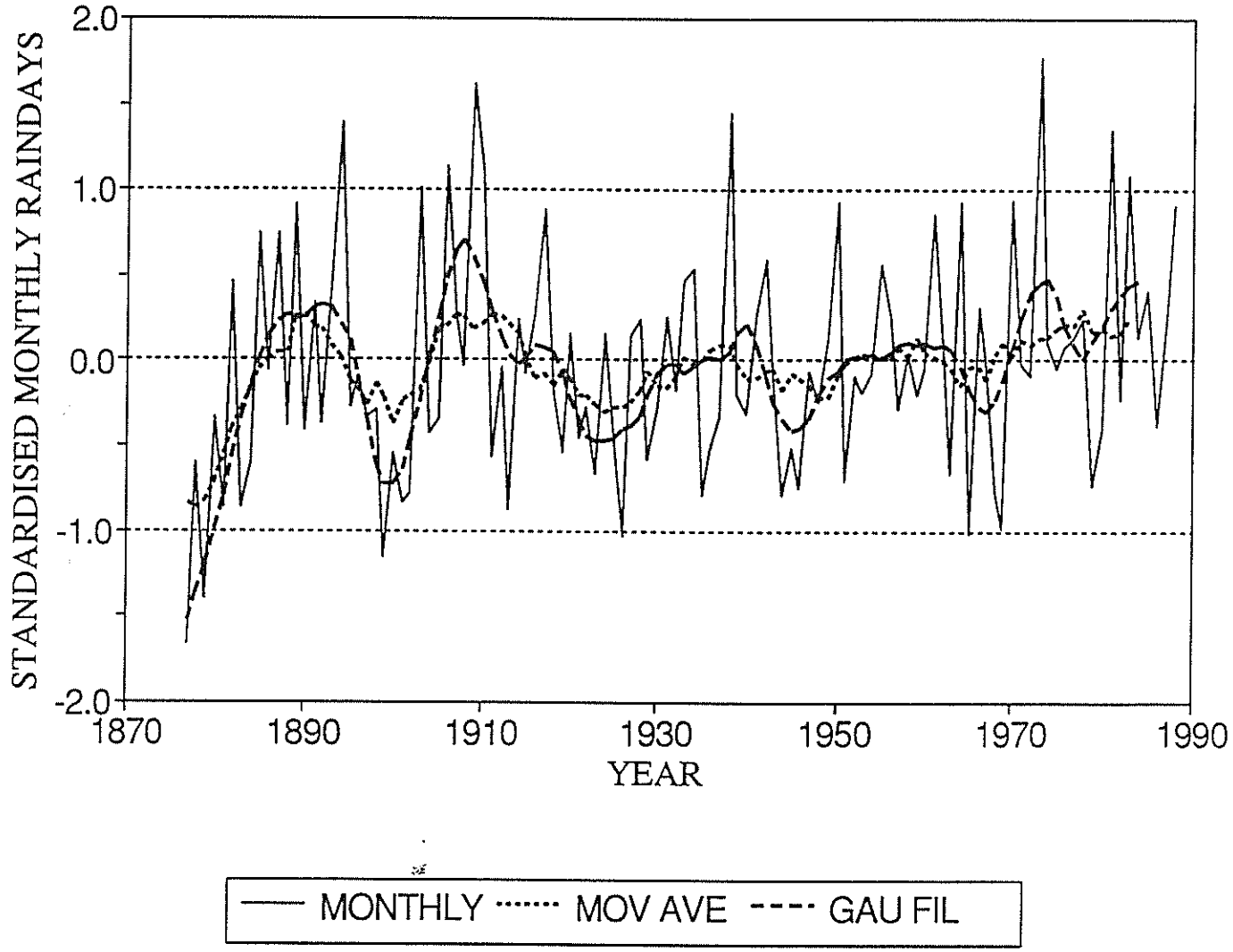


Fig C19. Plot of November raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - tropical region.

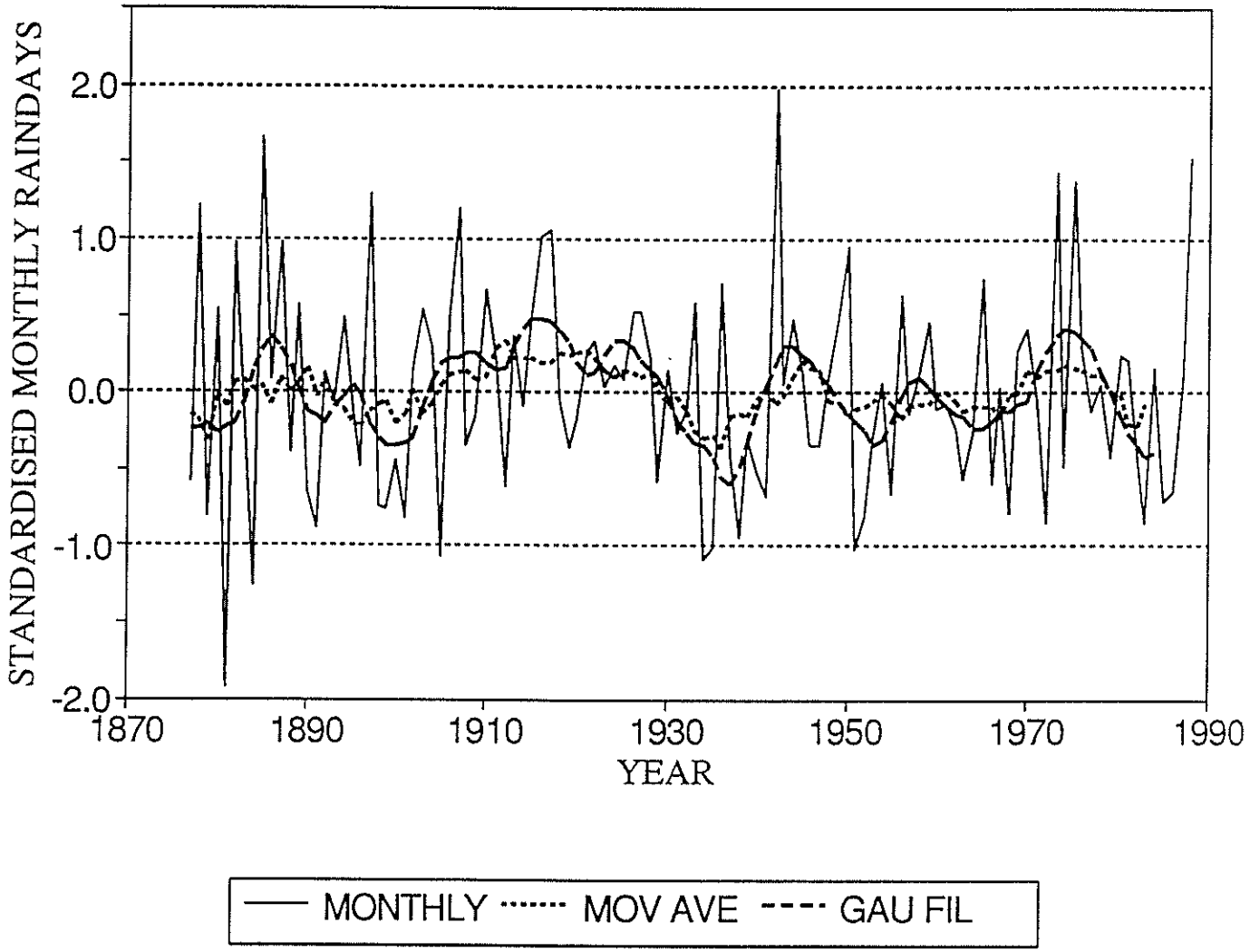


Fig C20. Plot of December raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - tropical region.

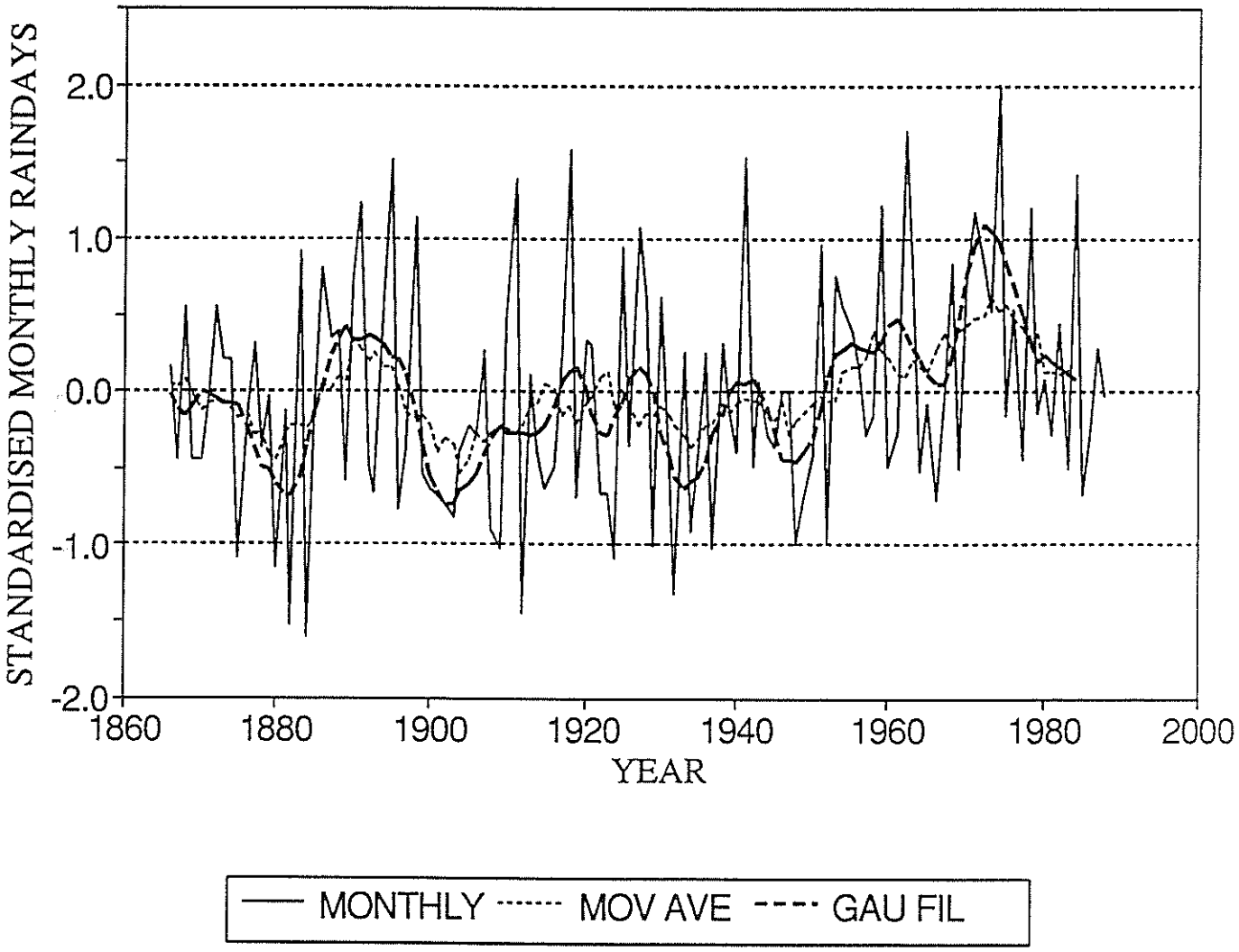


Fig C21. Plot of January raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - sub-tropical region.

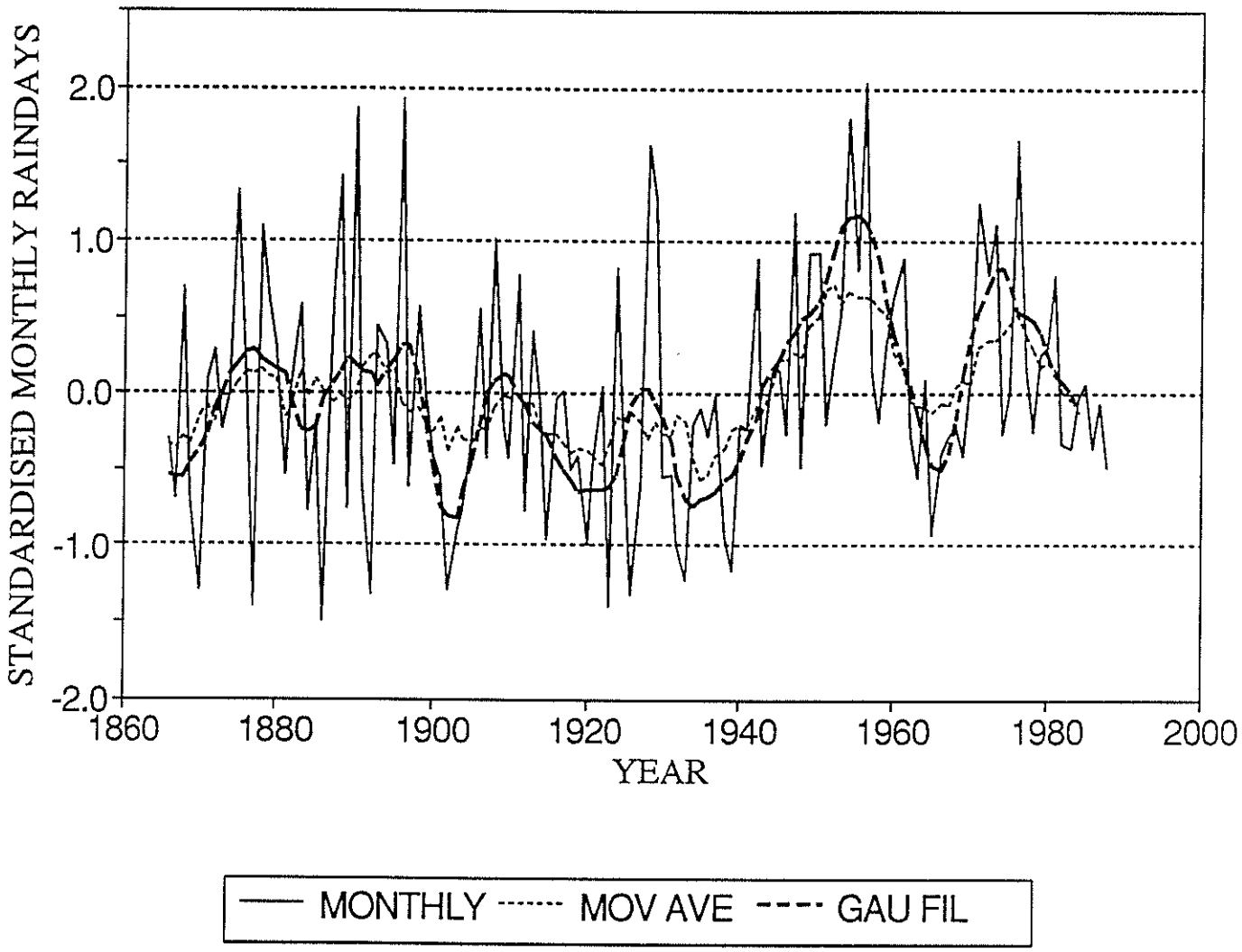


Fig C22. Plot of February raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - sub-tropical region.

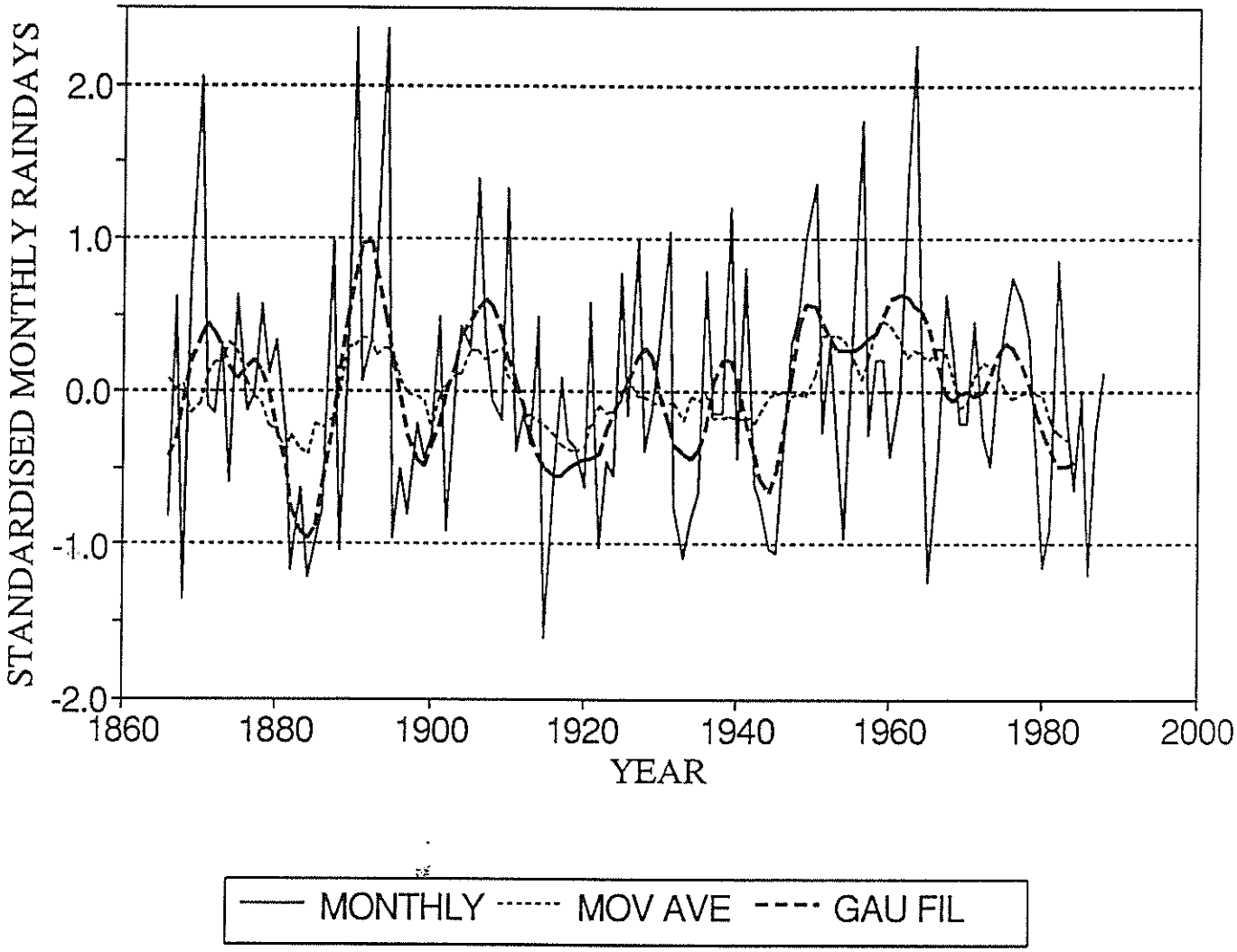


Fig C23. Plot of March raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - sub-tropical region.

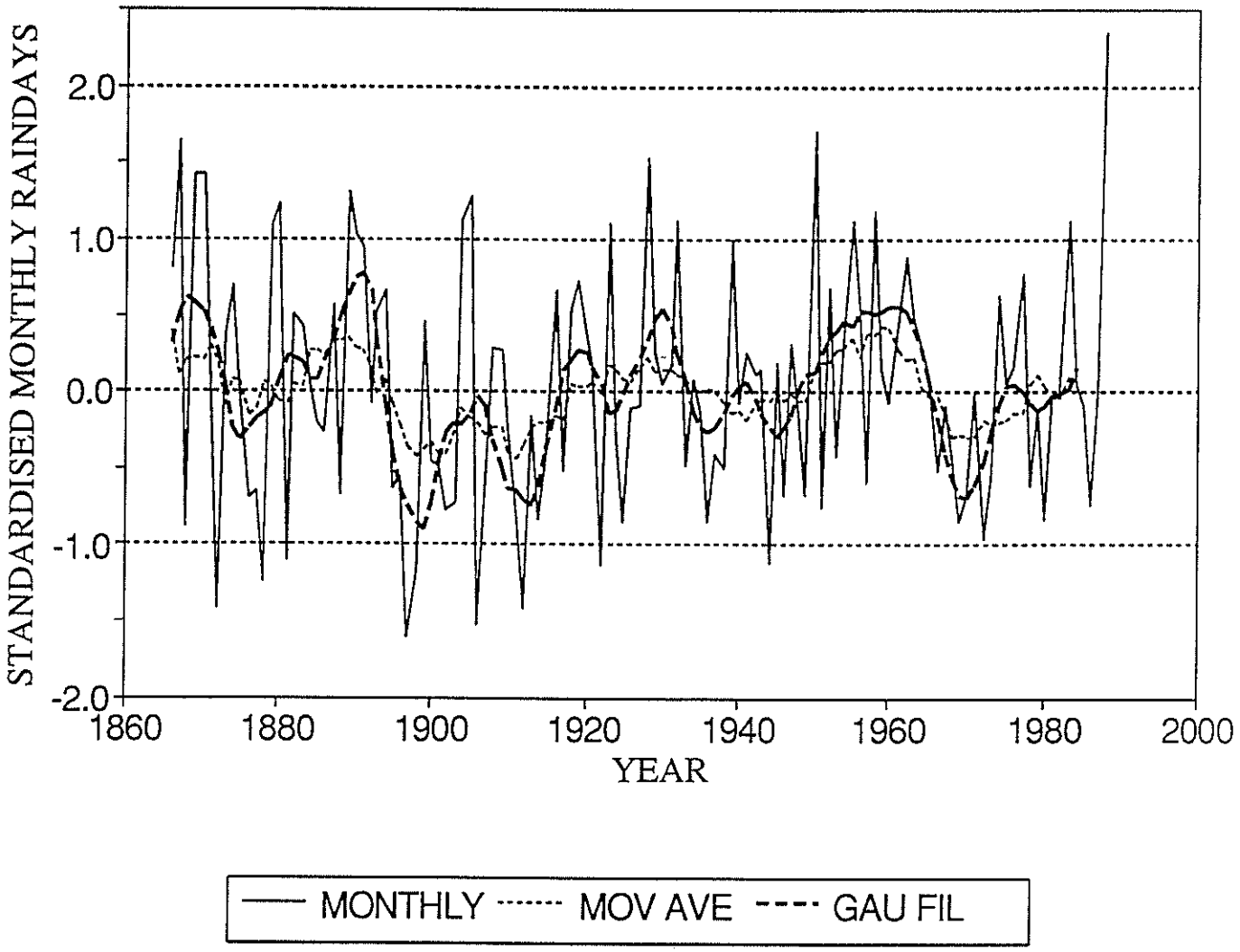


Fig C24. Plot of April raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - sub-tropical region.

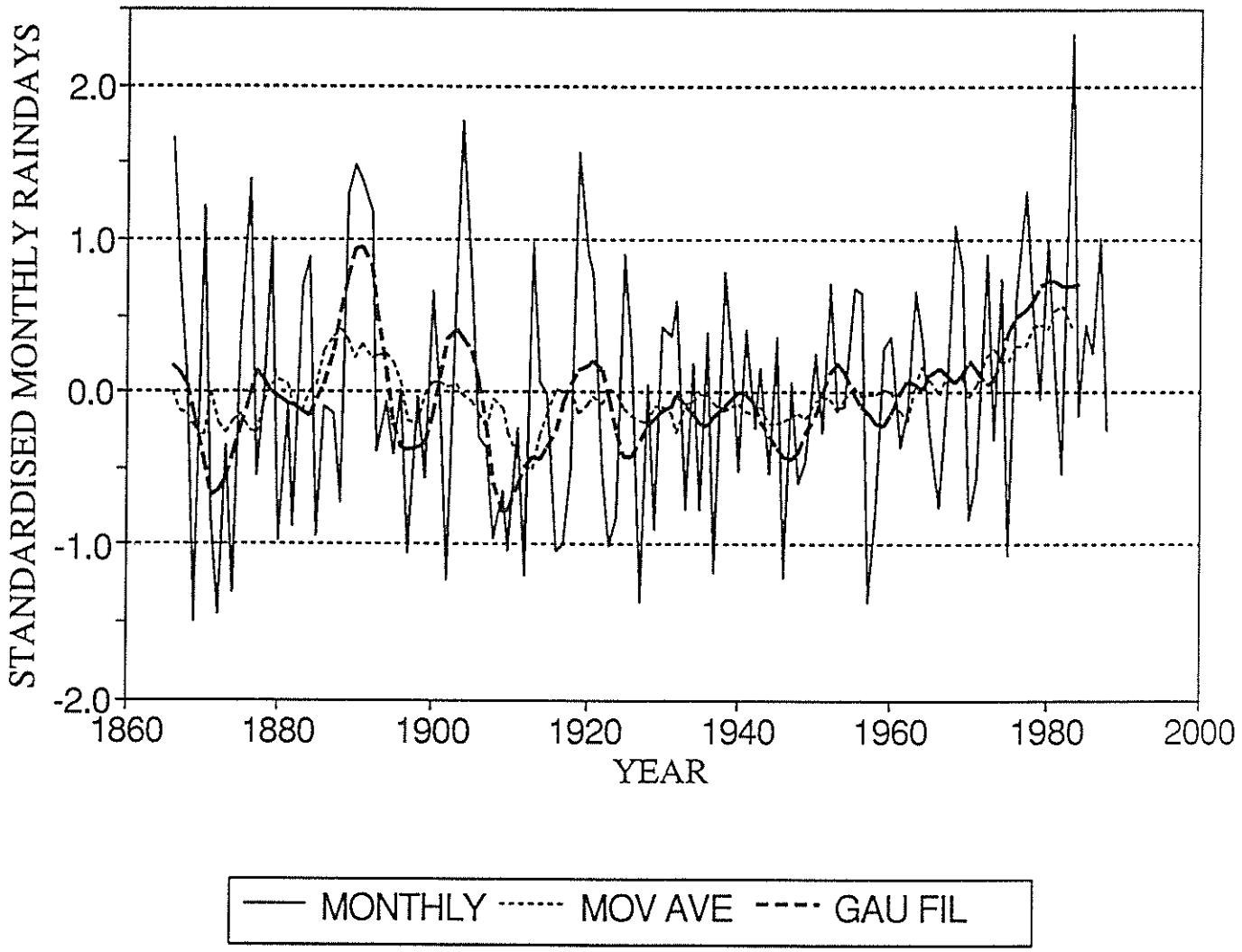


Fig C25. Plot of May raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - sub-tropical region.

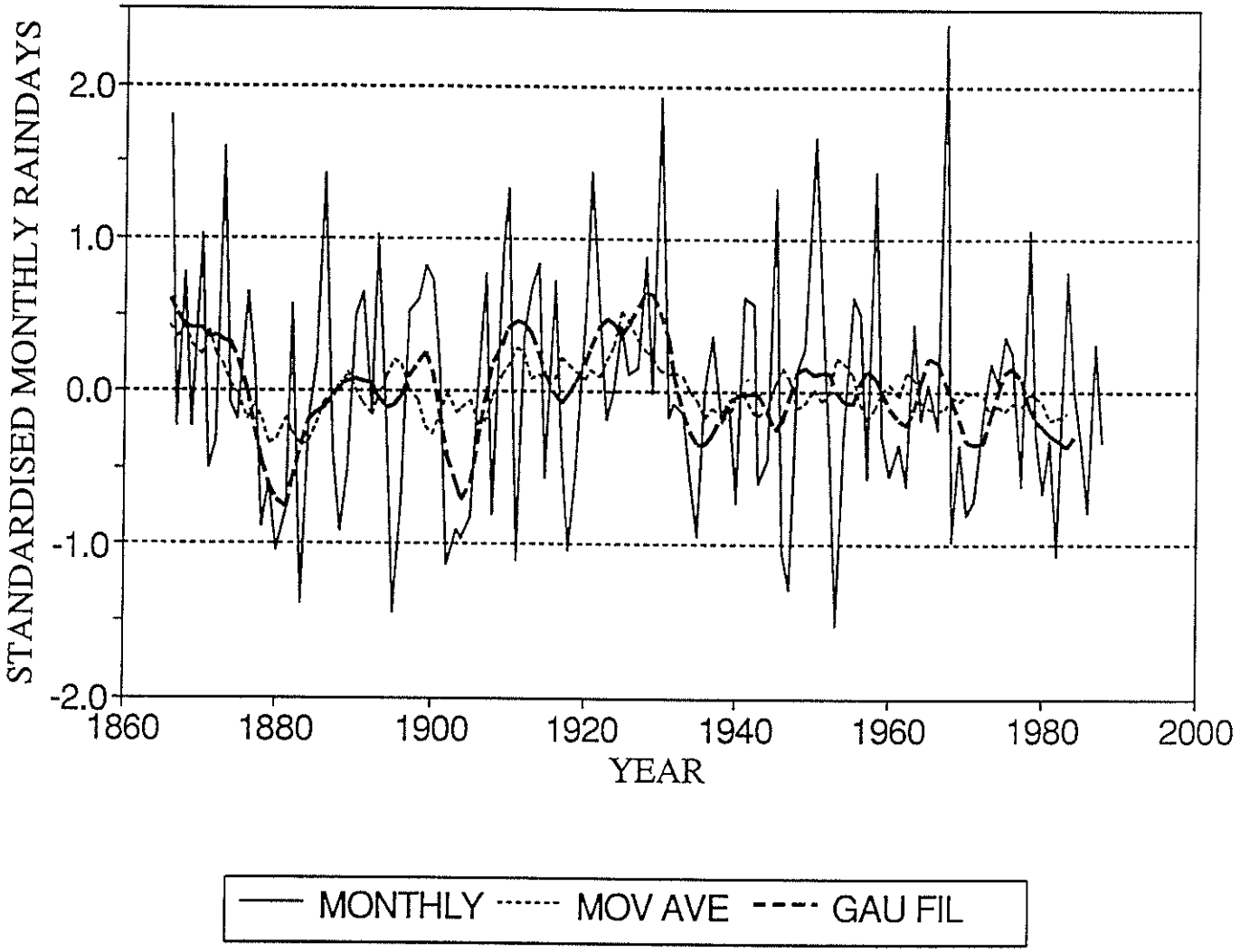


Fig C26. Plot of June raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - sub-tropical region.

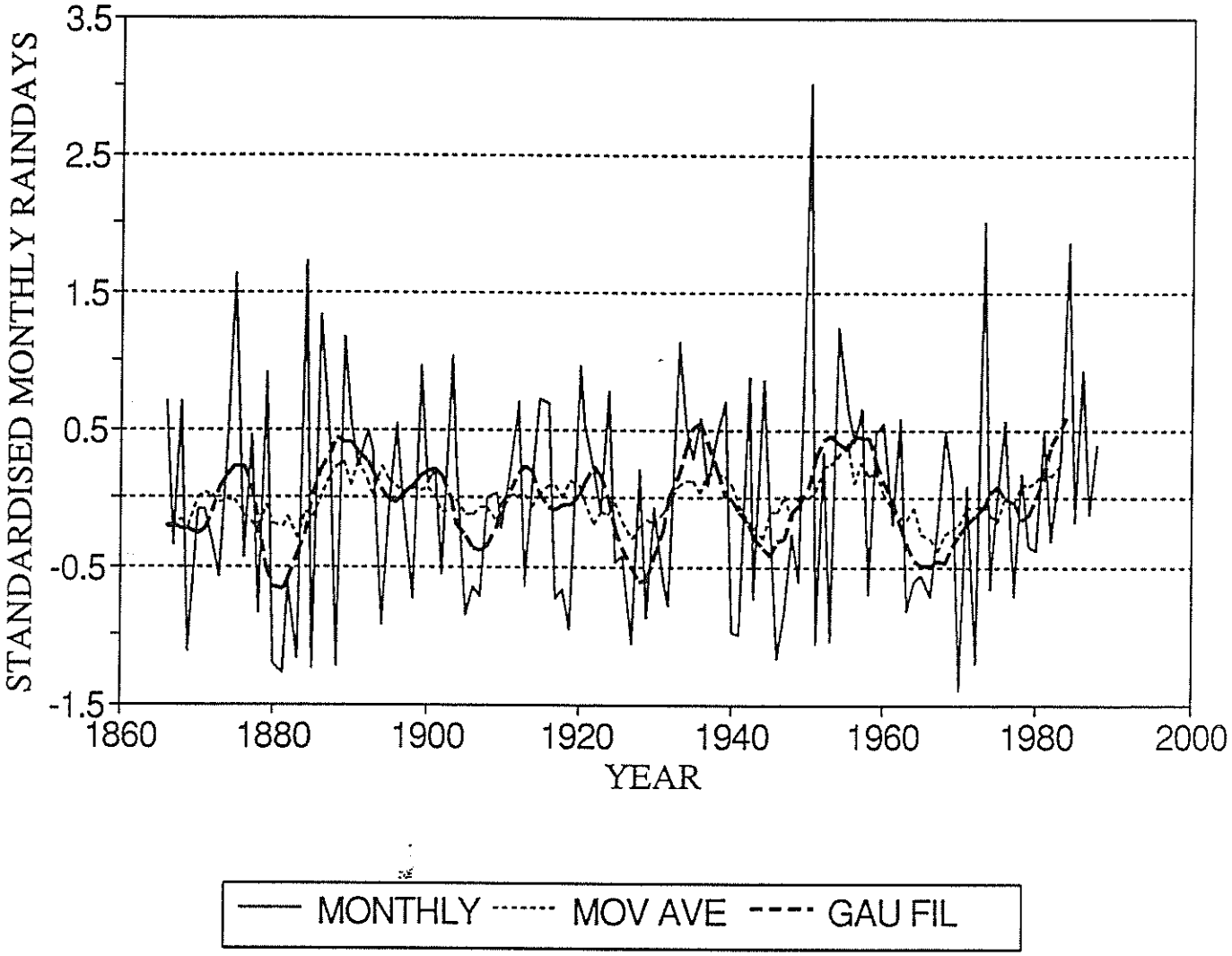


Fig C27. Plot of July raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - sub-tropical region.

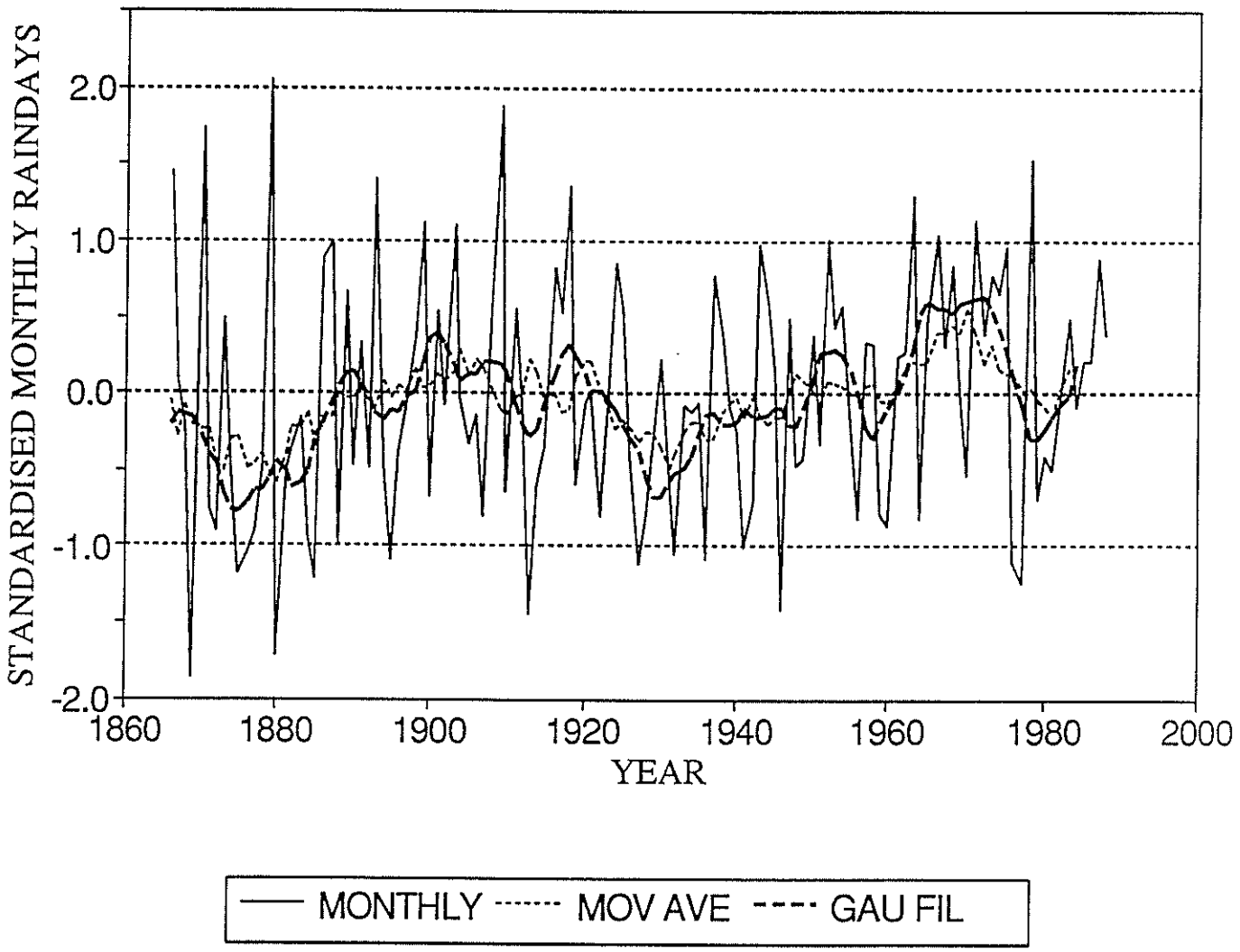


Fig C28. Plot of August raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - sub-tropical region.

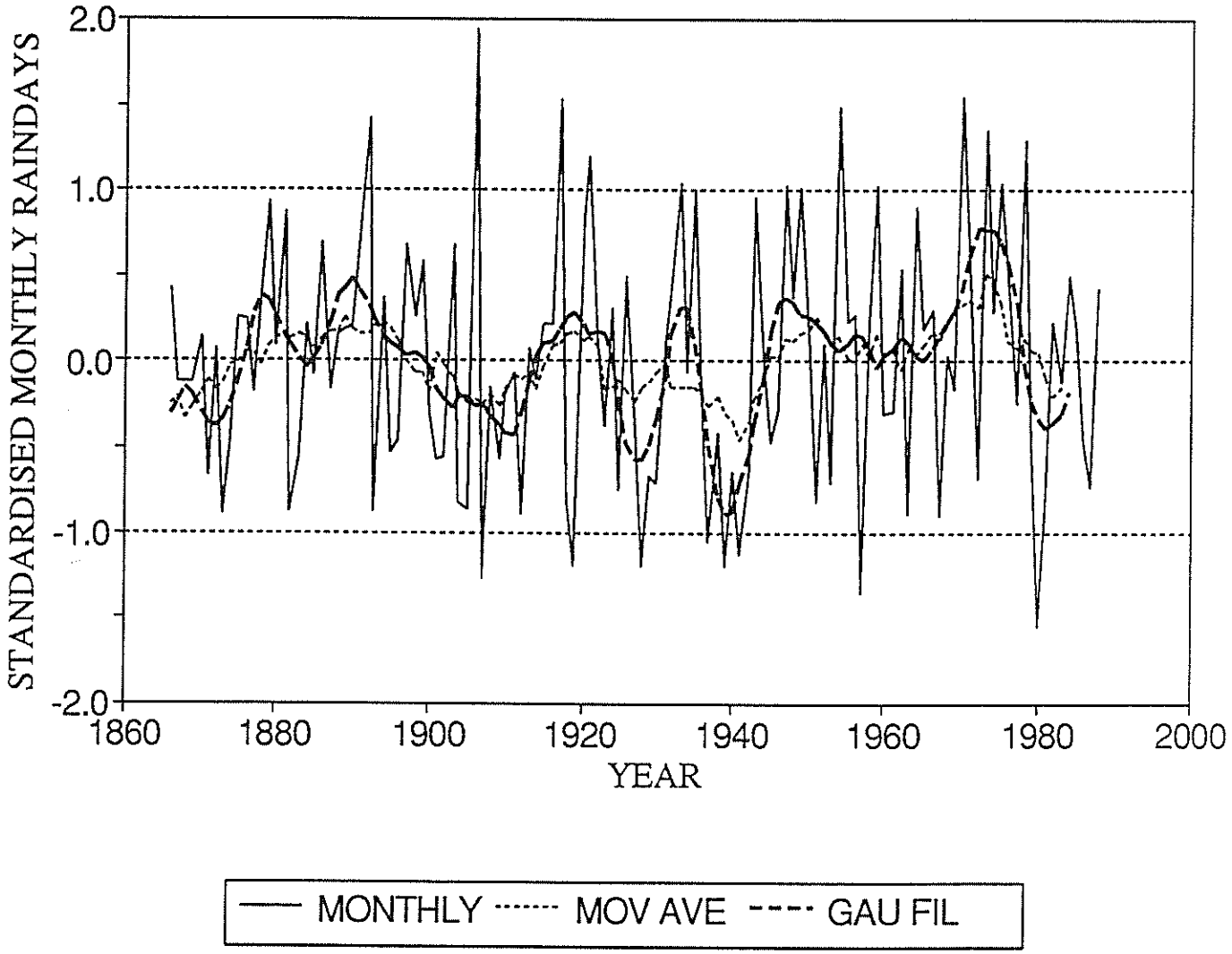


Fig C29. Plot of September raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - sub-tropical region.

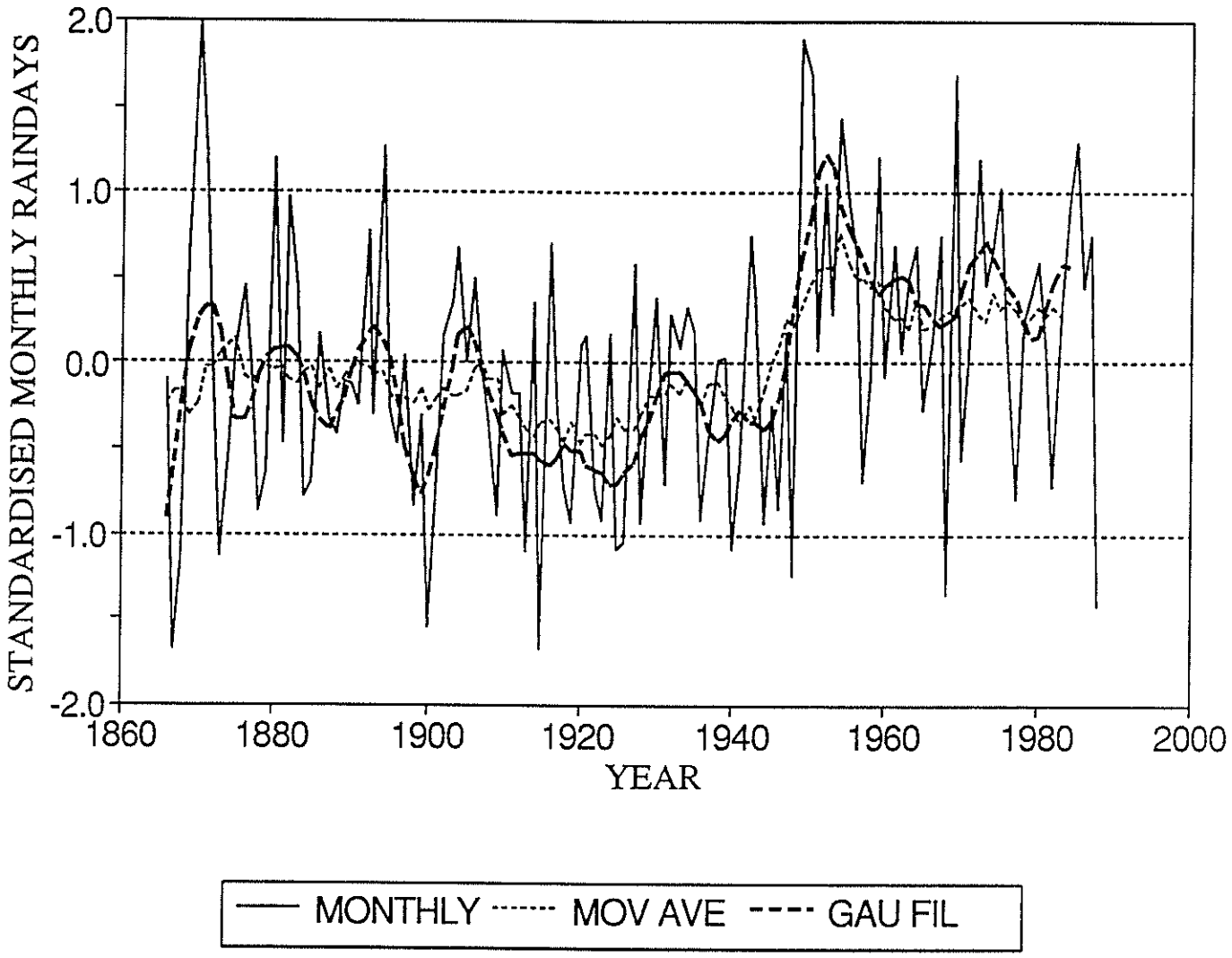


Fig C30. Plot of October raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - sub-tropical region.

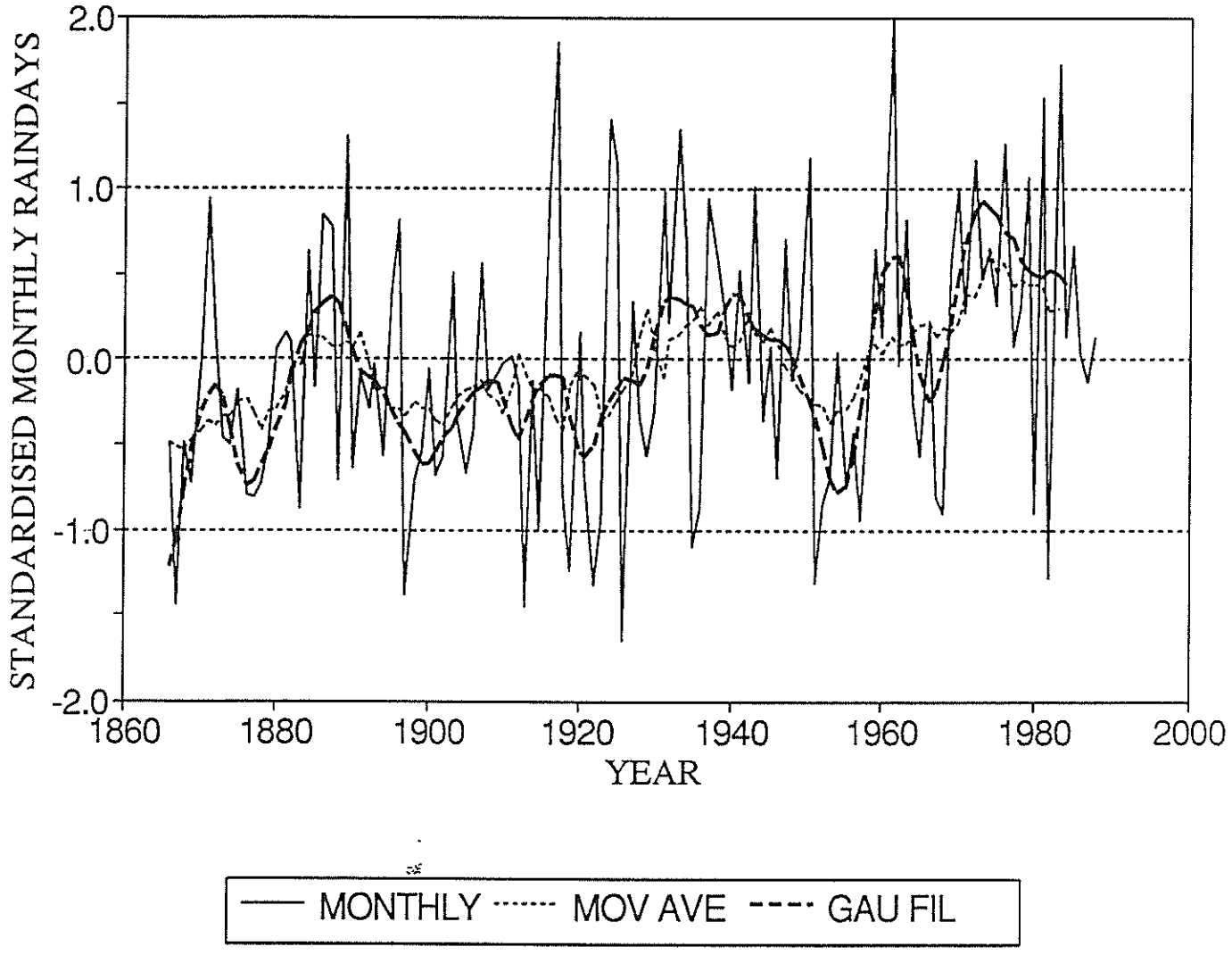


Fig C31. Plot of November raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - sub-tropical region.

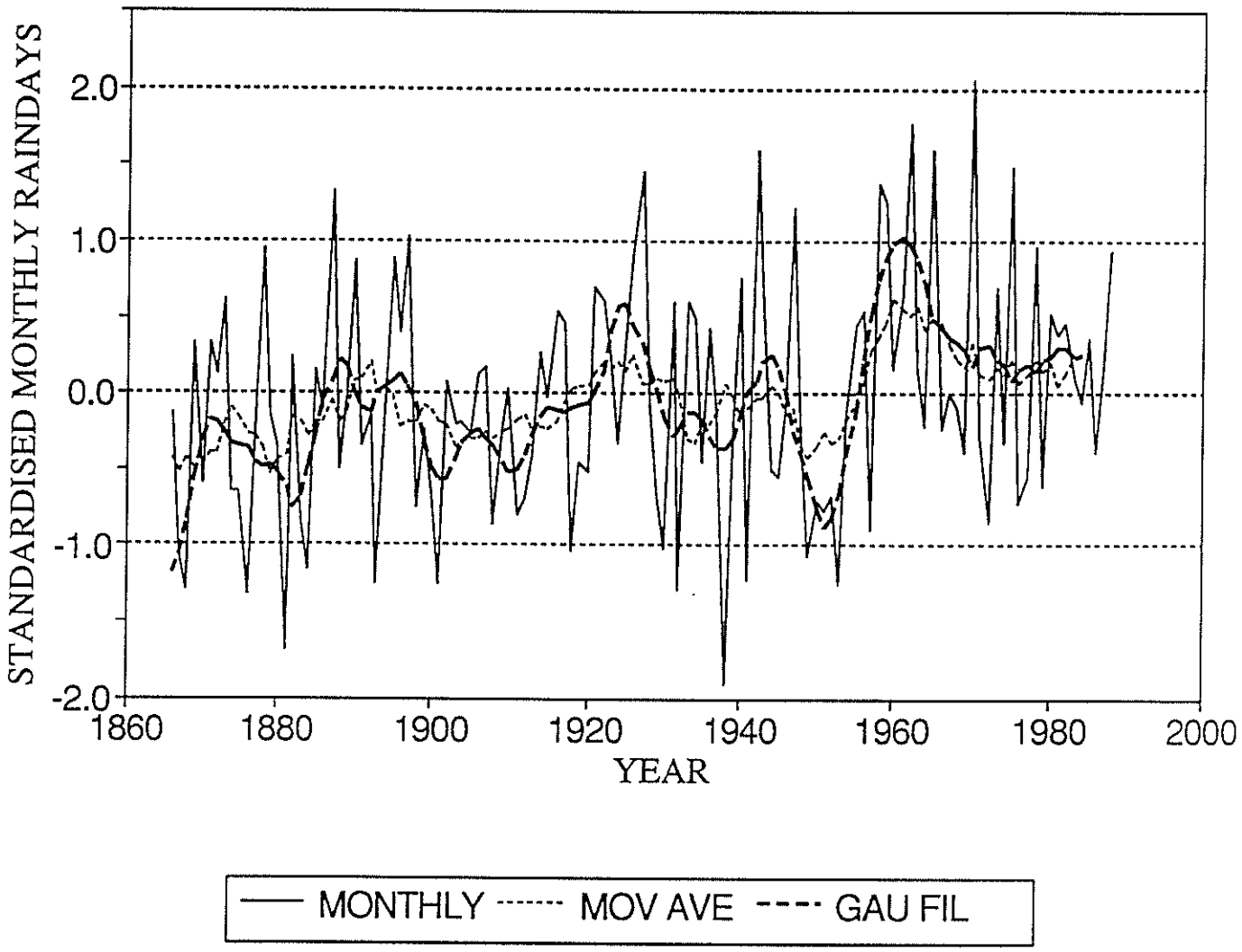


Fig C32. Plot of December raindays time series with 11 year moving average and 11 point Gaussian filter for summer rainfall - sub-tropical region.

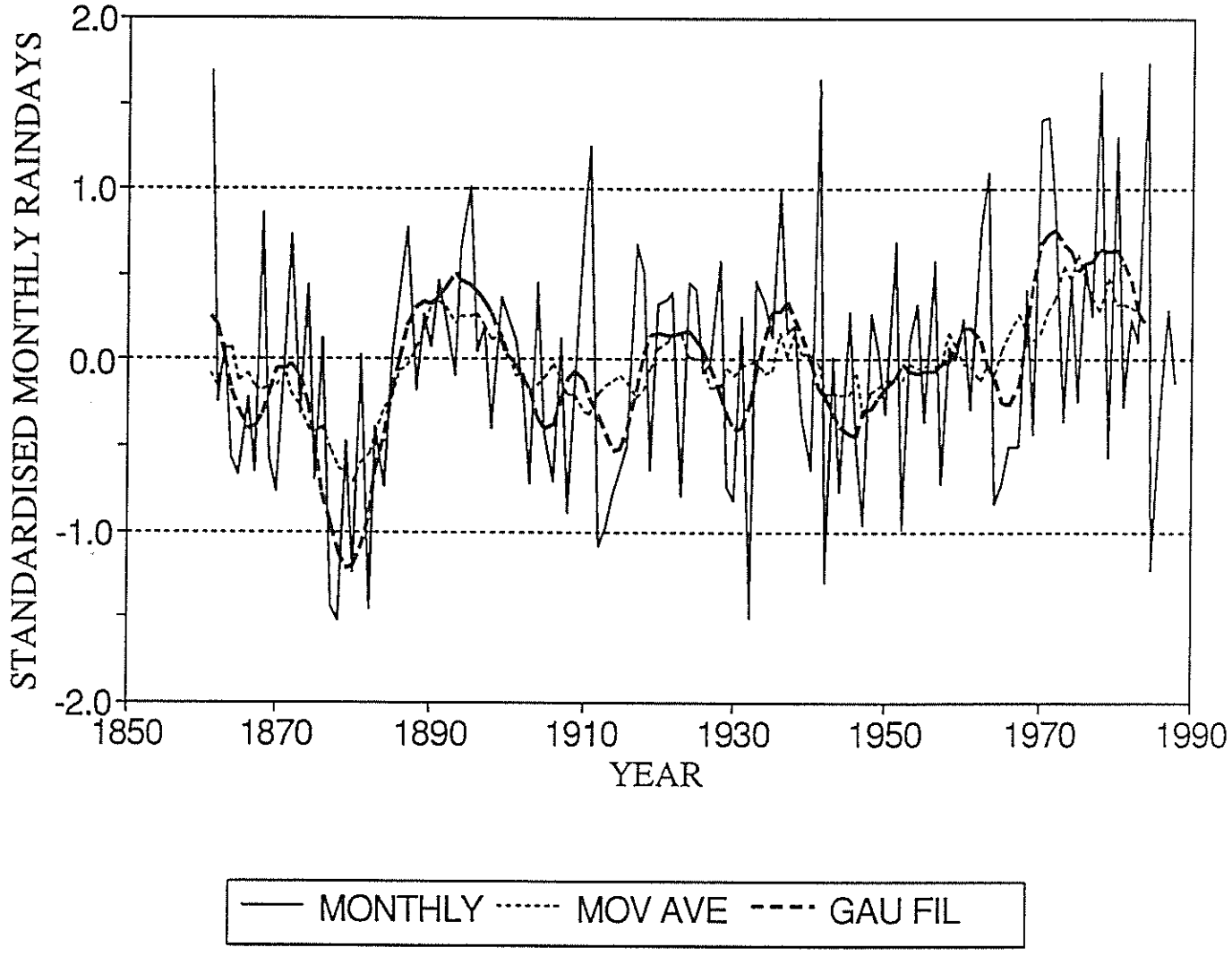


Fig C33. Plot of January raindays time series with 11 year moving average and 11 point Gaussian filter for uniform rainfall - temperate region.

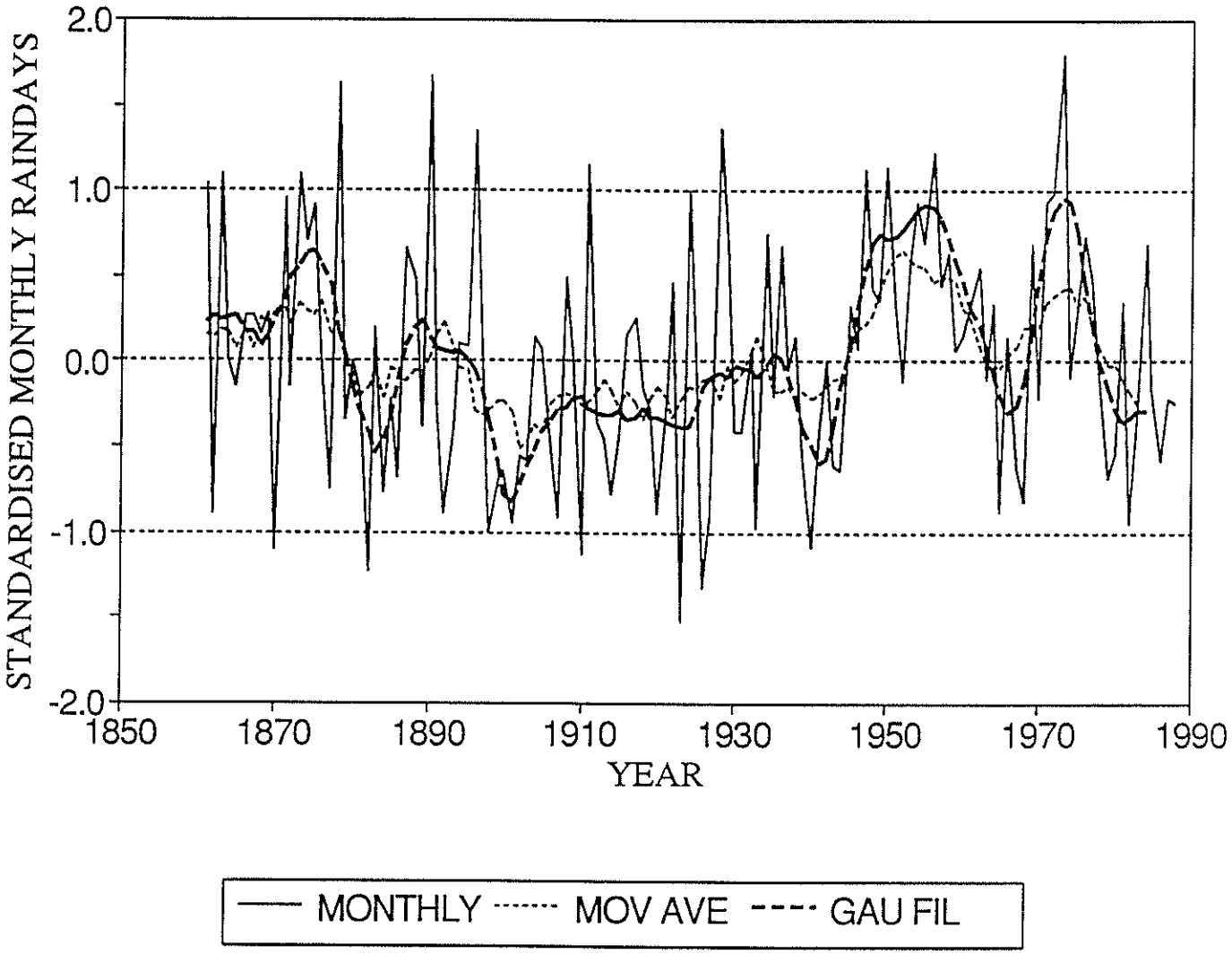


Fig C34. Plot of February raindays time series with 11 year moving average and 11 point Gaussian filter for uniform rainfall - temperate region.

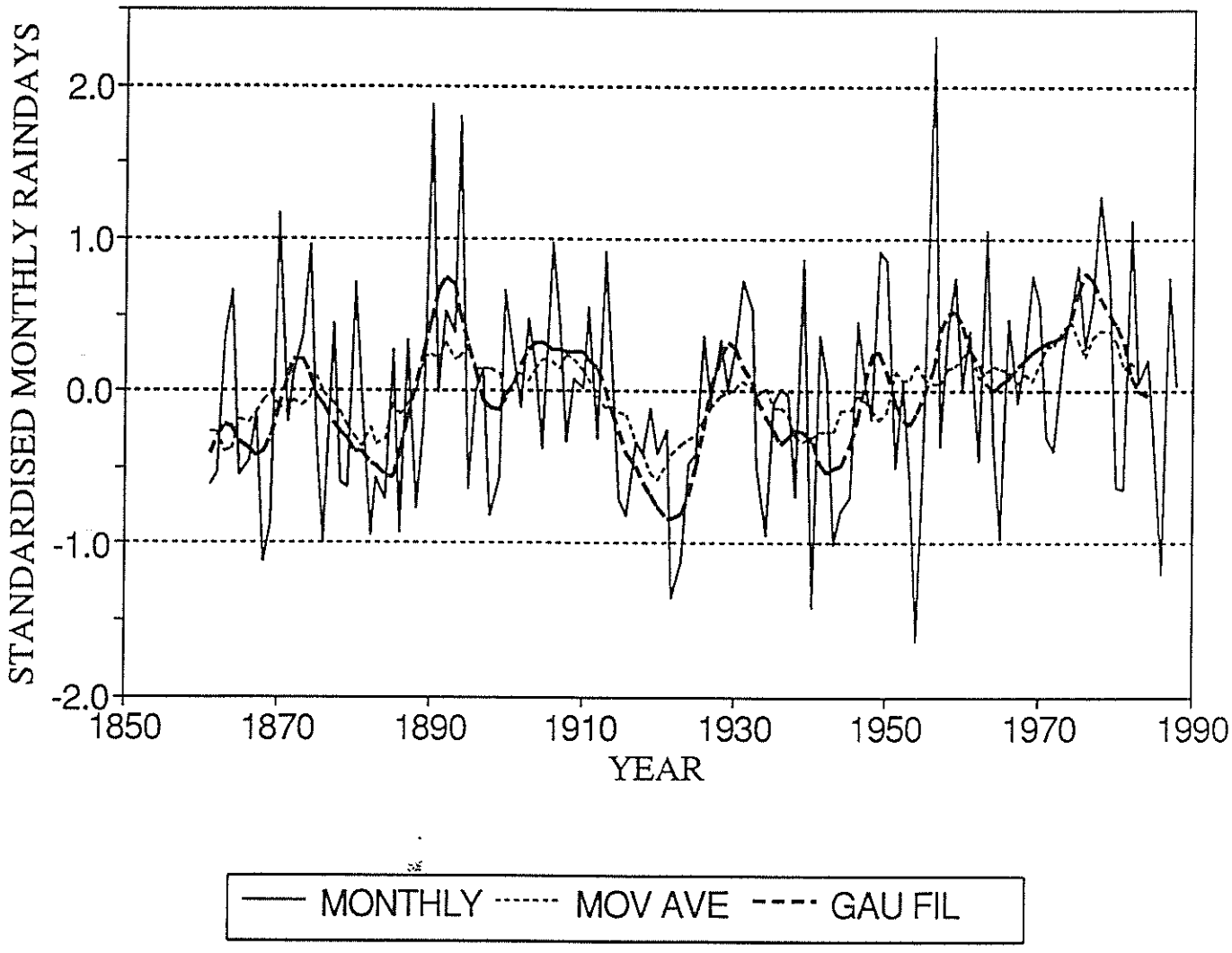


Fig C35. Plot of March raindays time series with 11 year moving average and 11 point Gaussian filter for uniform rainfall - temperate region.

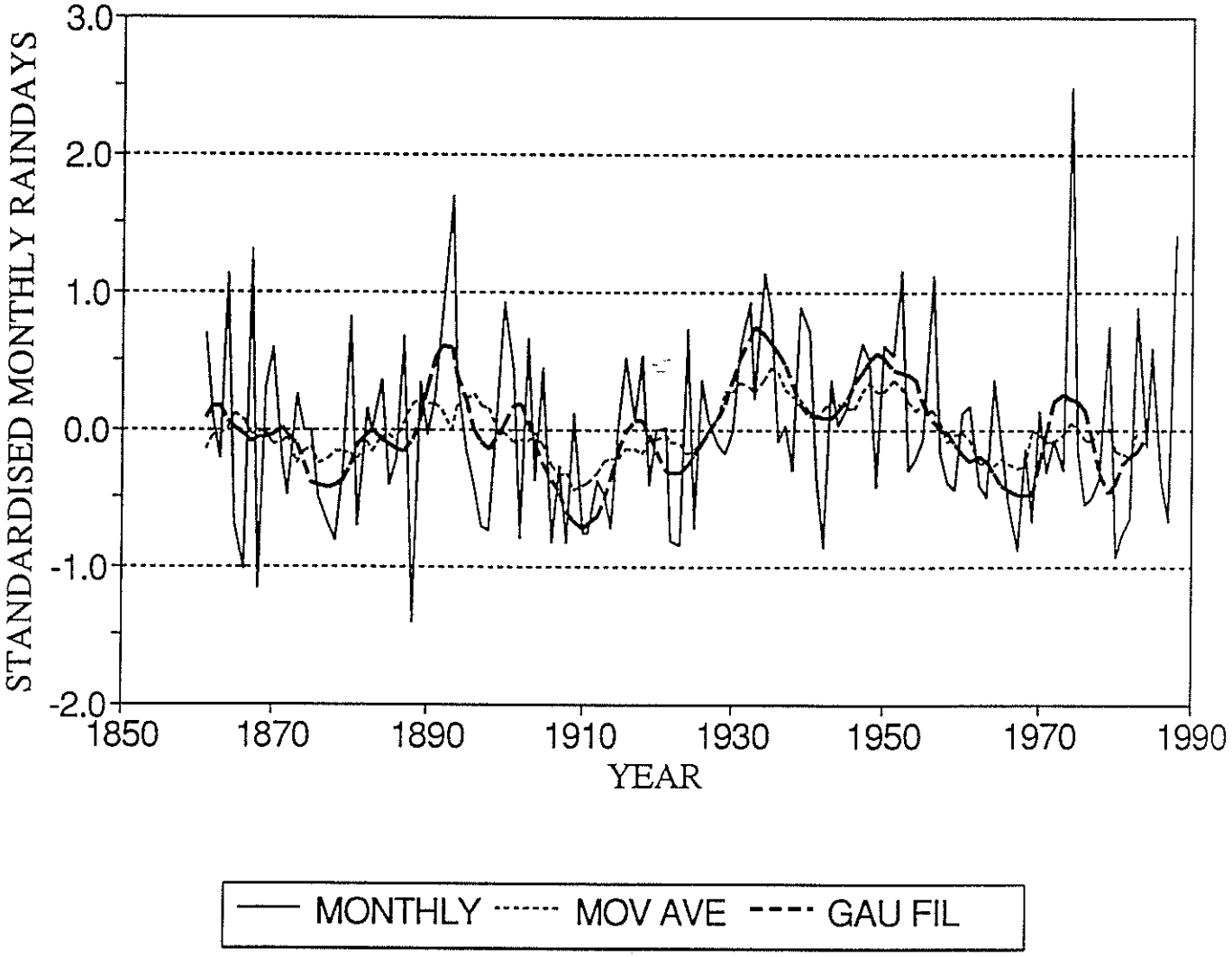


Fig C36. Plot of April raindays time series with 11 year moving average and 11 point Gaussian filter for uniform rainfall - temperate region.

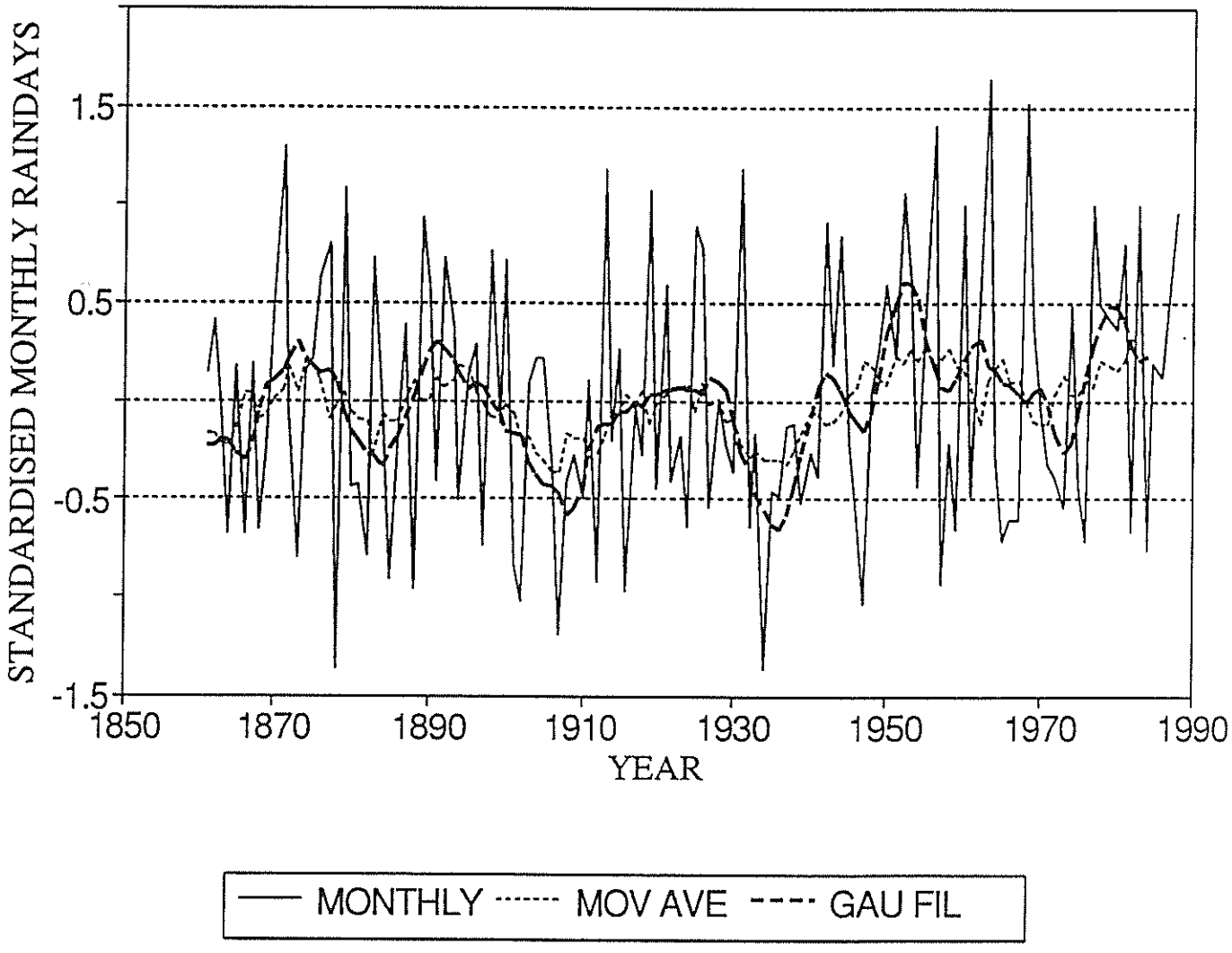


Fig C37. Plot of May raindays time series with 11 year moving average and 11 point Gaussian filter for uniform rainfall - temperate region.

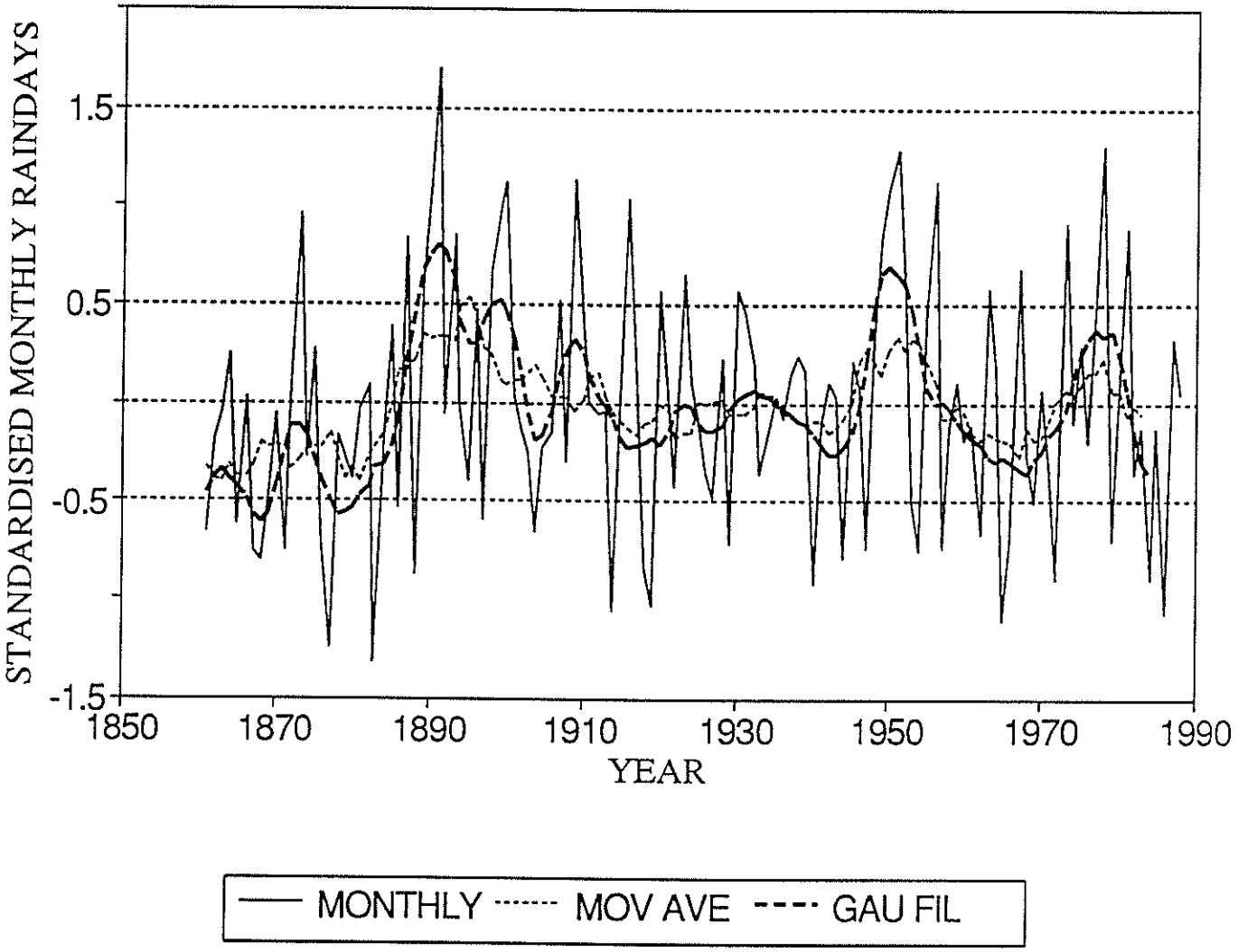


Fig C38. Plot of June raindays time series with 11 year moving average and 11 point Gaussian filter for uniform rainfall - temperate region.

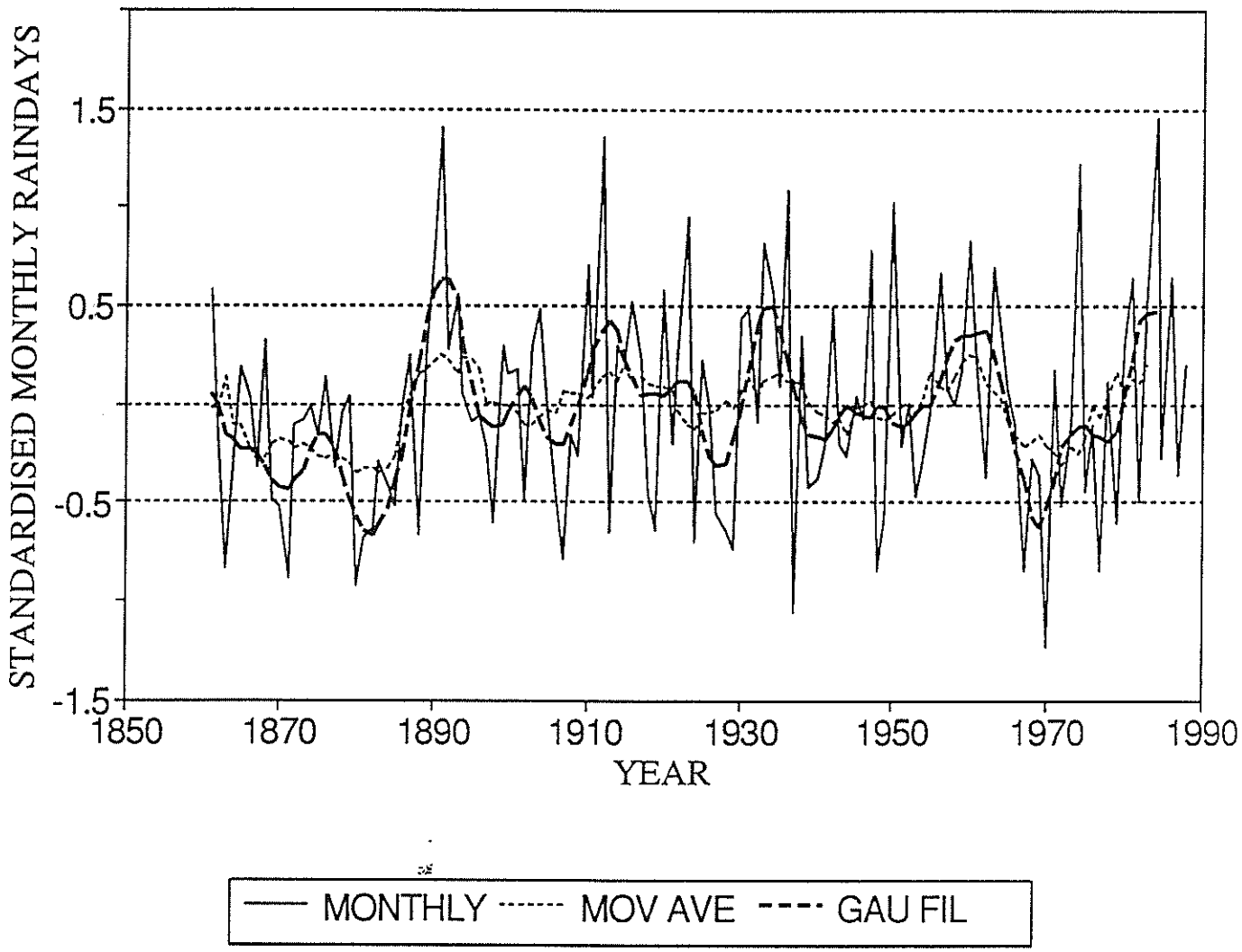


Fig C39. Plot of July raindays time series with 11 year moving average and 11 point Gaussian filter for uniform rainfall - temperate region.

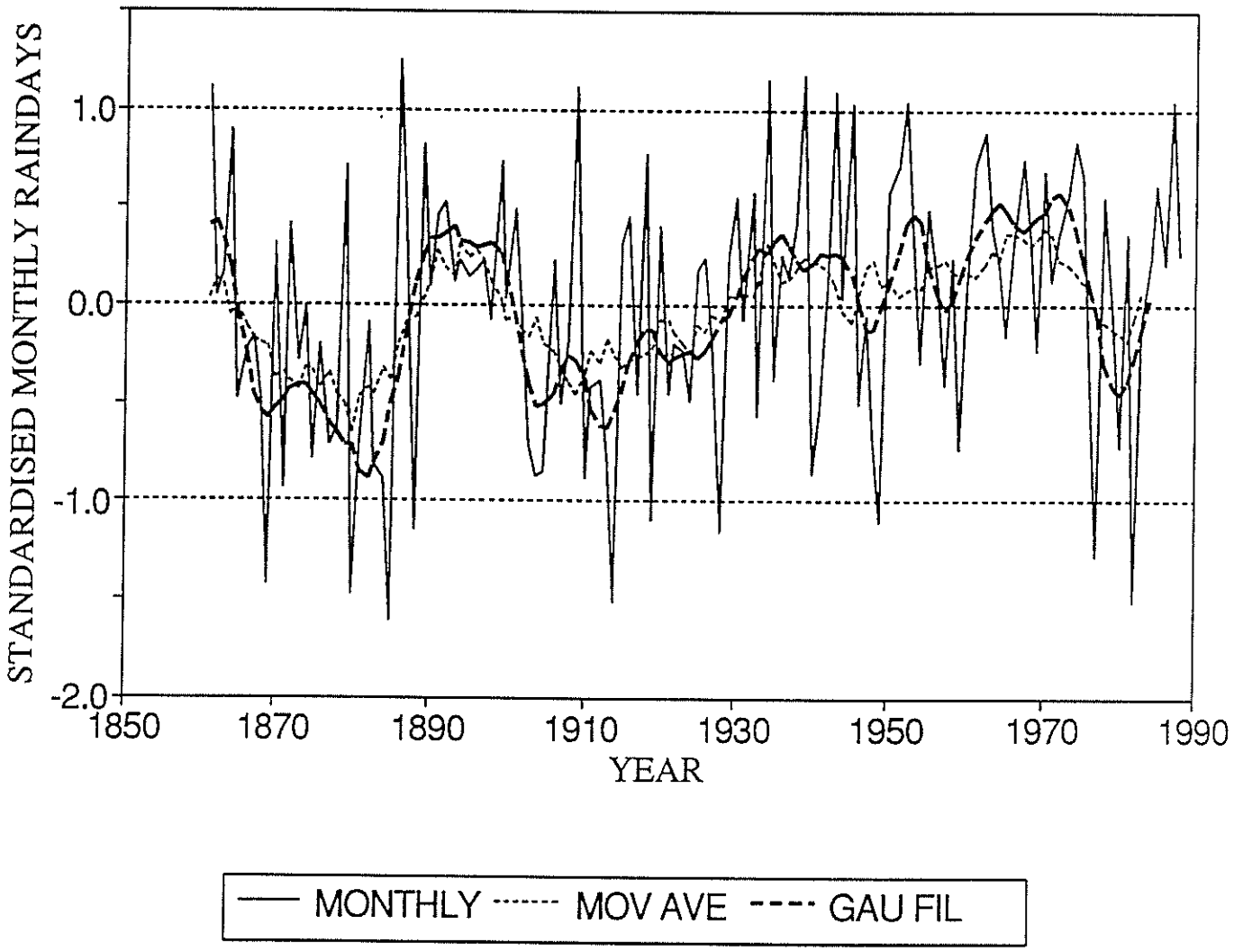


Fig C40. Plot of August raindays time series with 11 year moving average and 11 point Gaussian filter for uniform rainfall - temperate region.

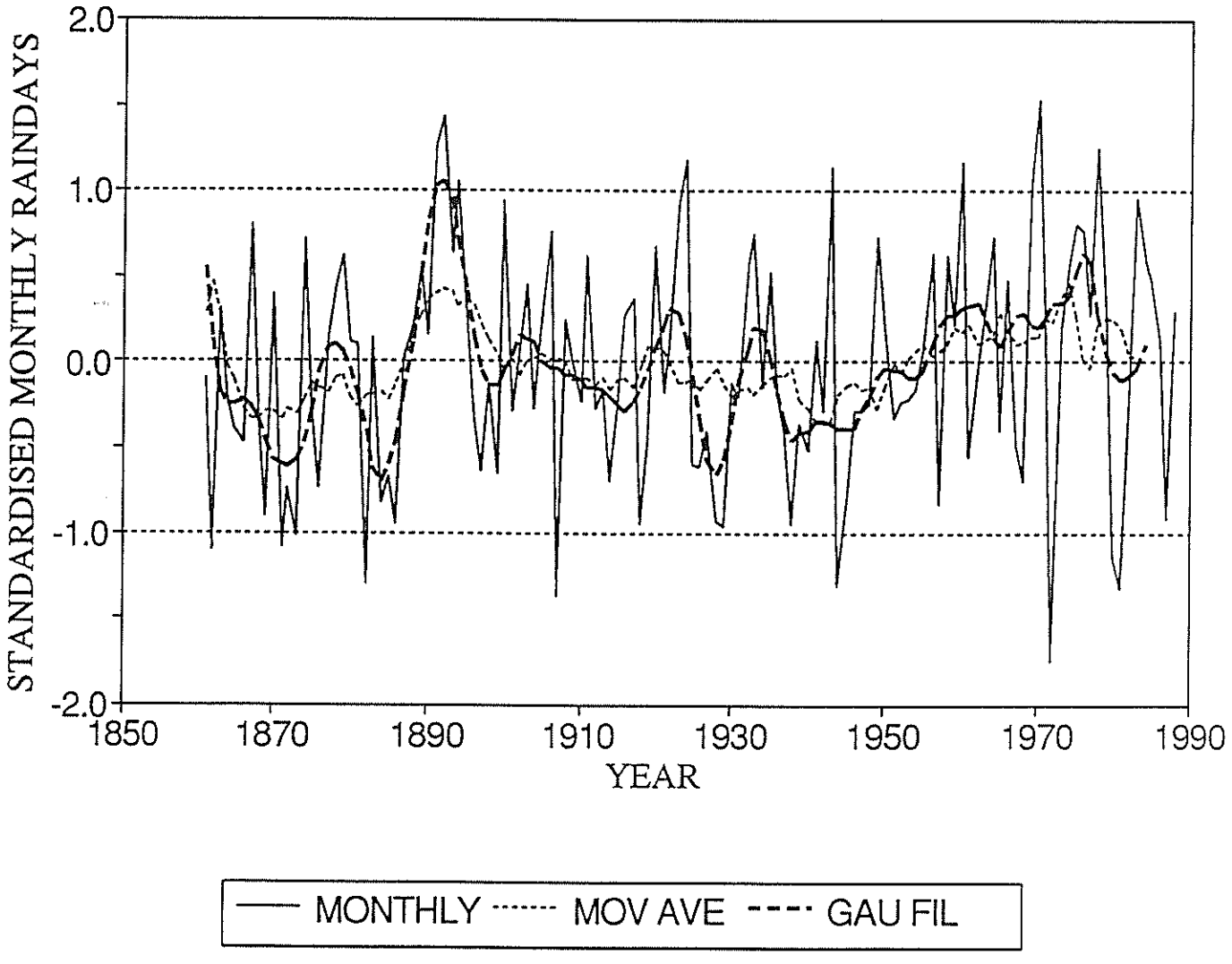


Fig C41. Plot of September raindays time series with 11 year moving average and 11 point Gaussian filter for uniform rainfall - temperate region.

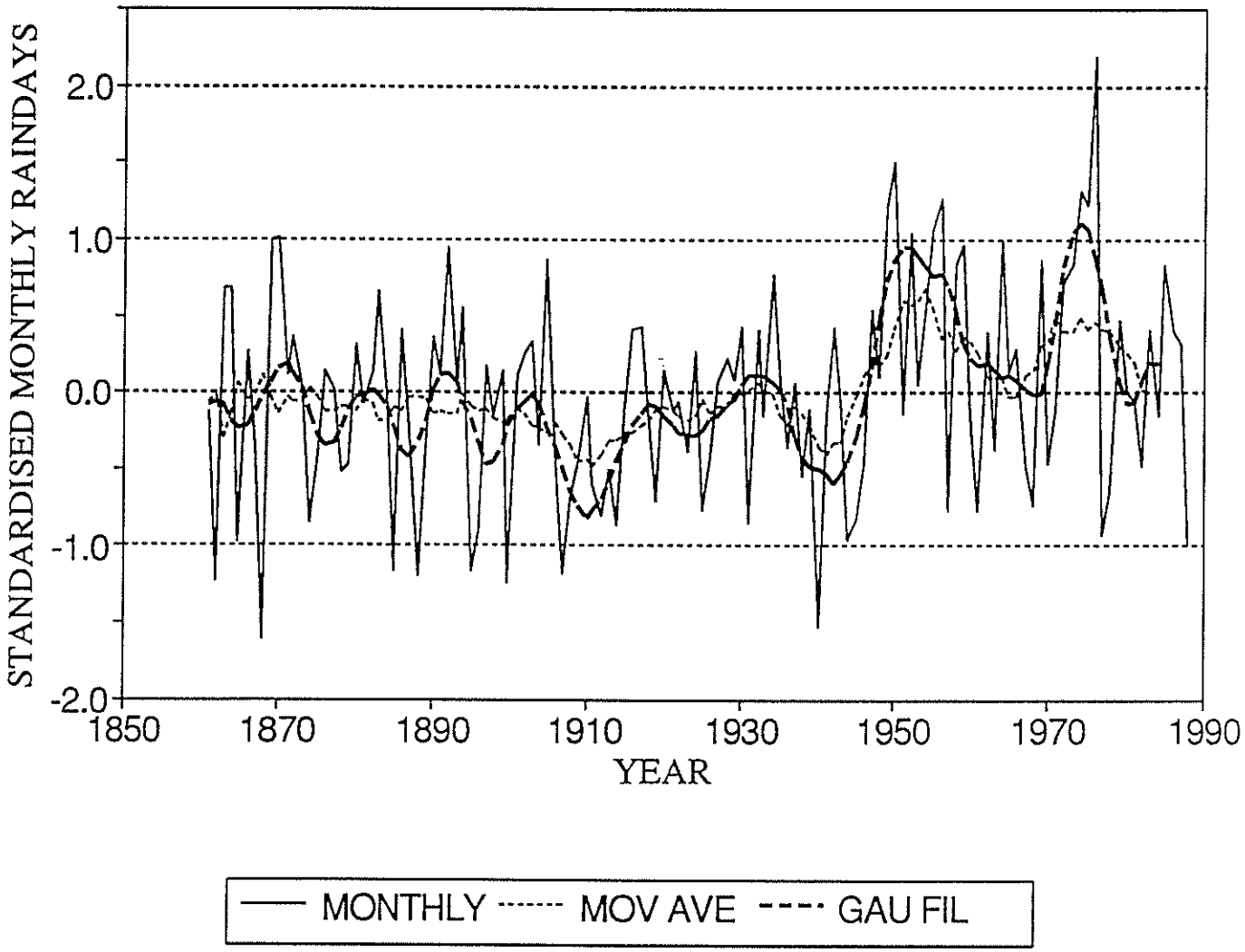


Fig C42. Plot of October raindays time series with 11 year moving average and 11 point Gaussian filter for uniform rainfall - temperate region.

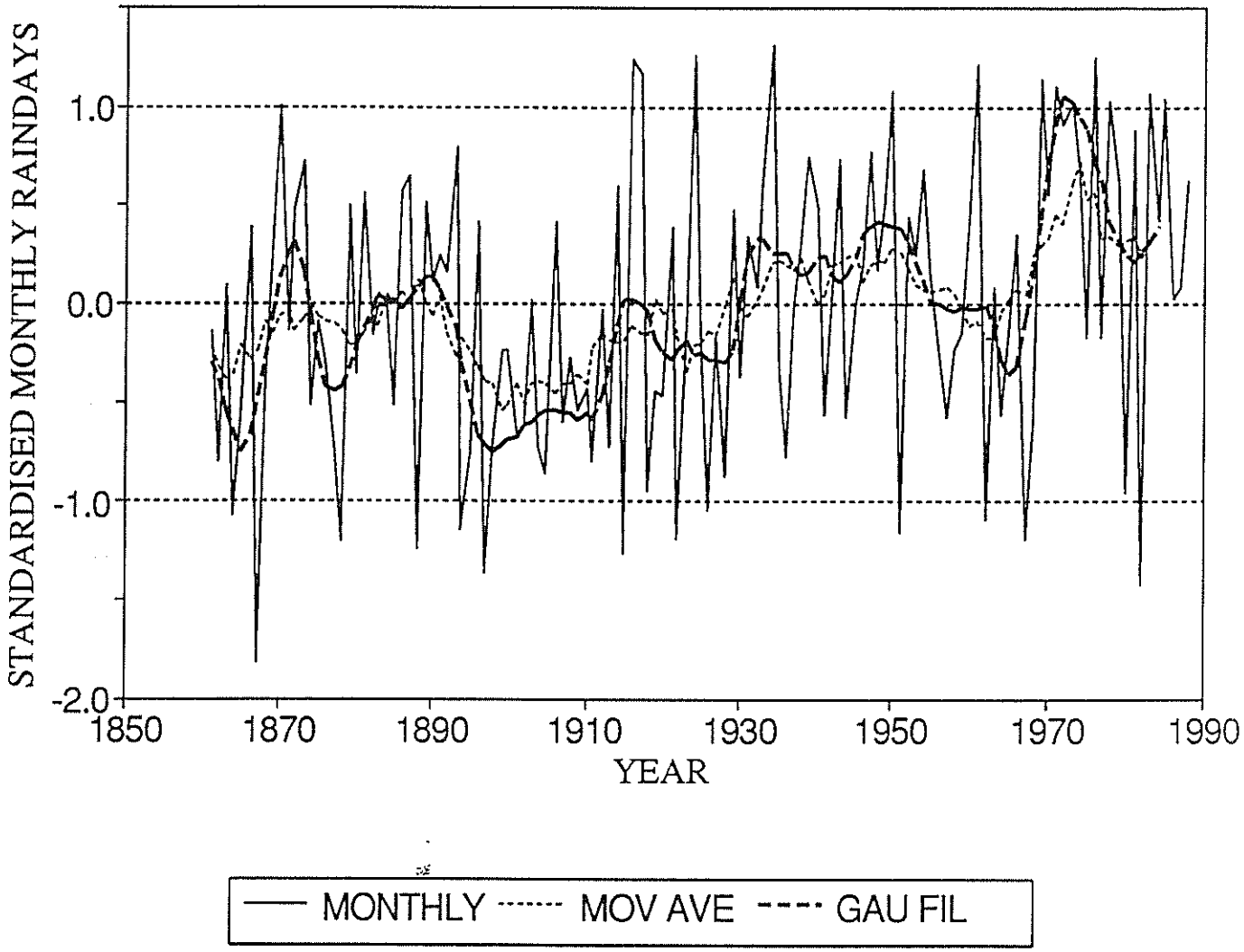


Fig C43. Plot of November raindays time series with 11 year moving average and 11 point Gaussian filter for uniform rainfall - temperate region.

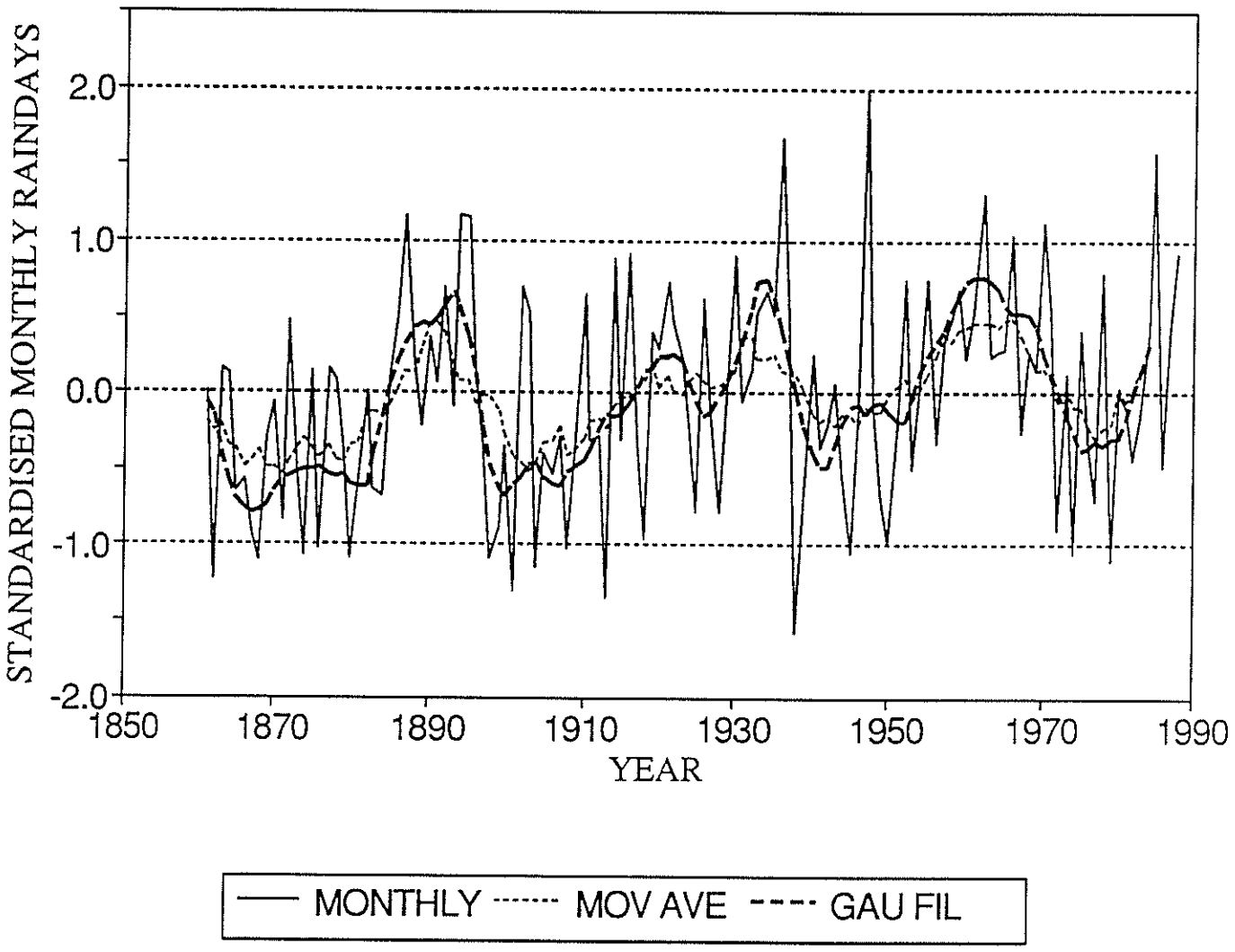


Fig C44. Plot of December raindays time series with 11 year moving average and 11 point Gaussian filter for uniform rainfall - temperate region.

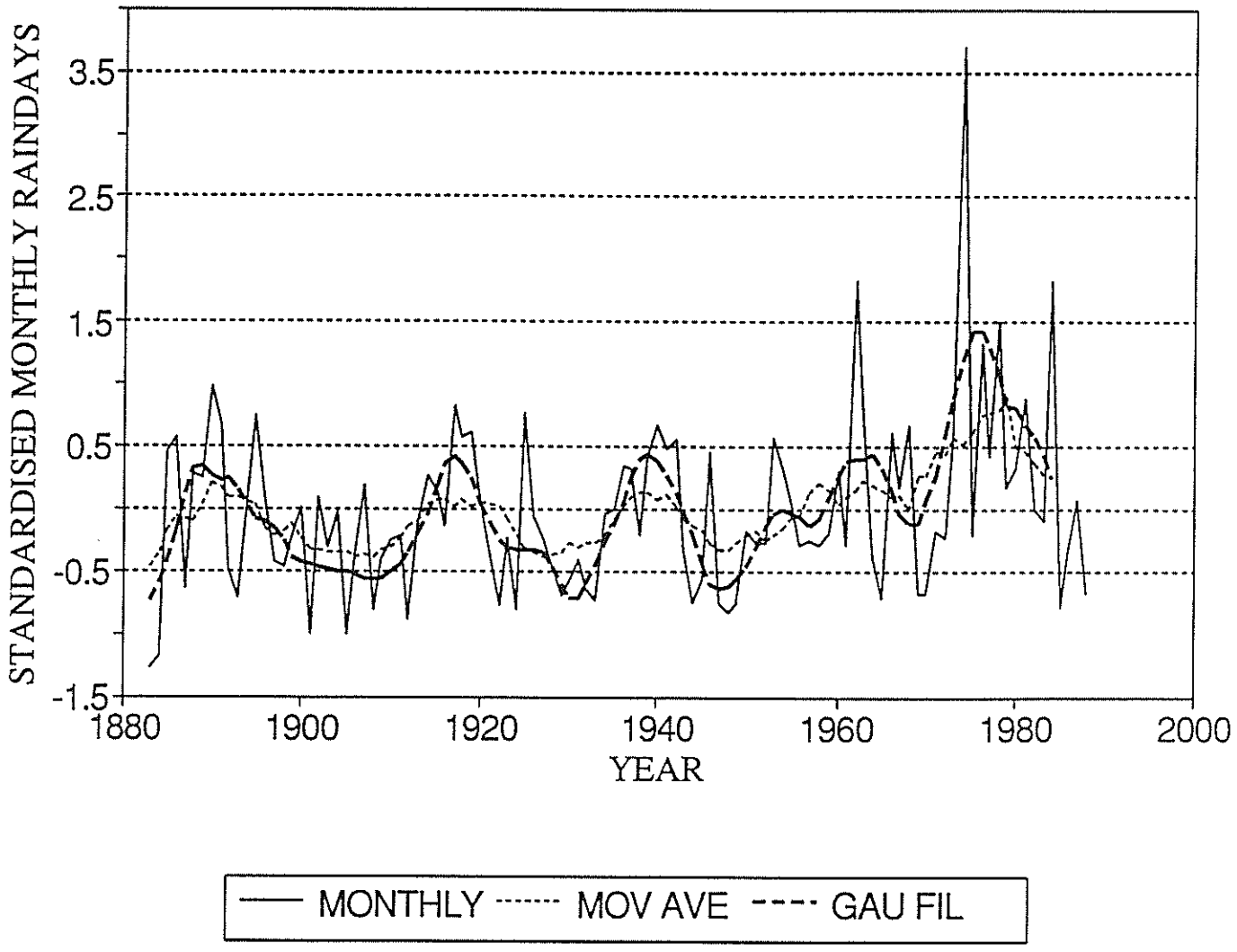


Fig C45. Plot of January raindays time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

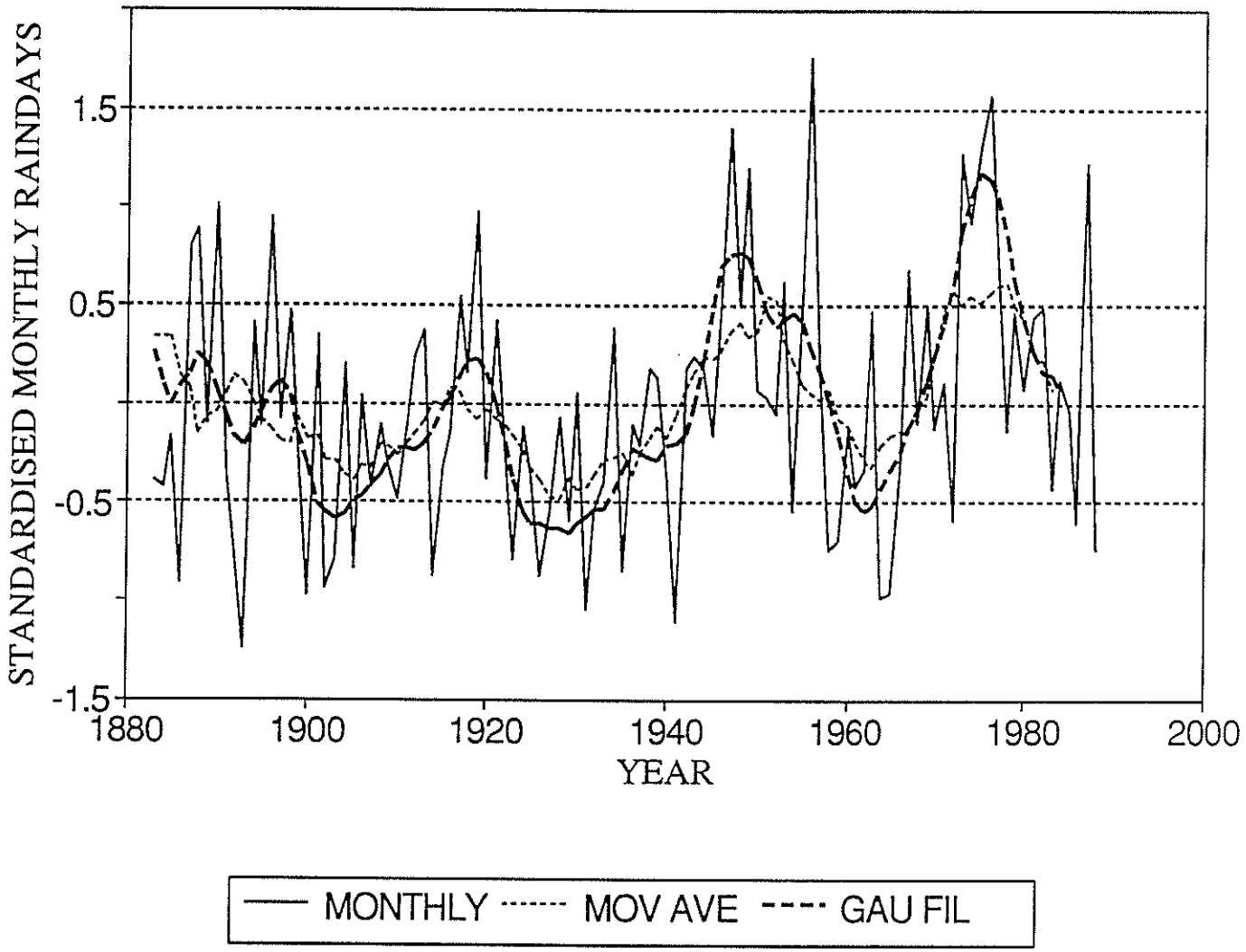


Fig C46. Plot of February raindays time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

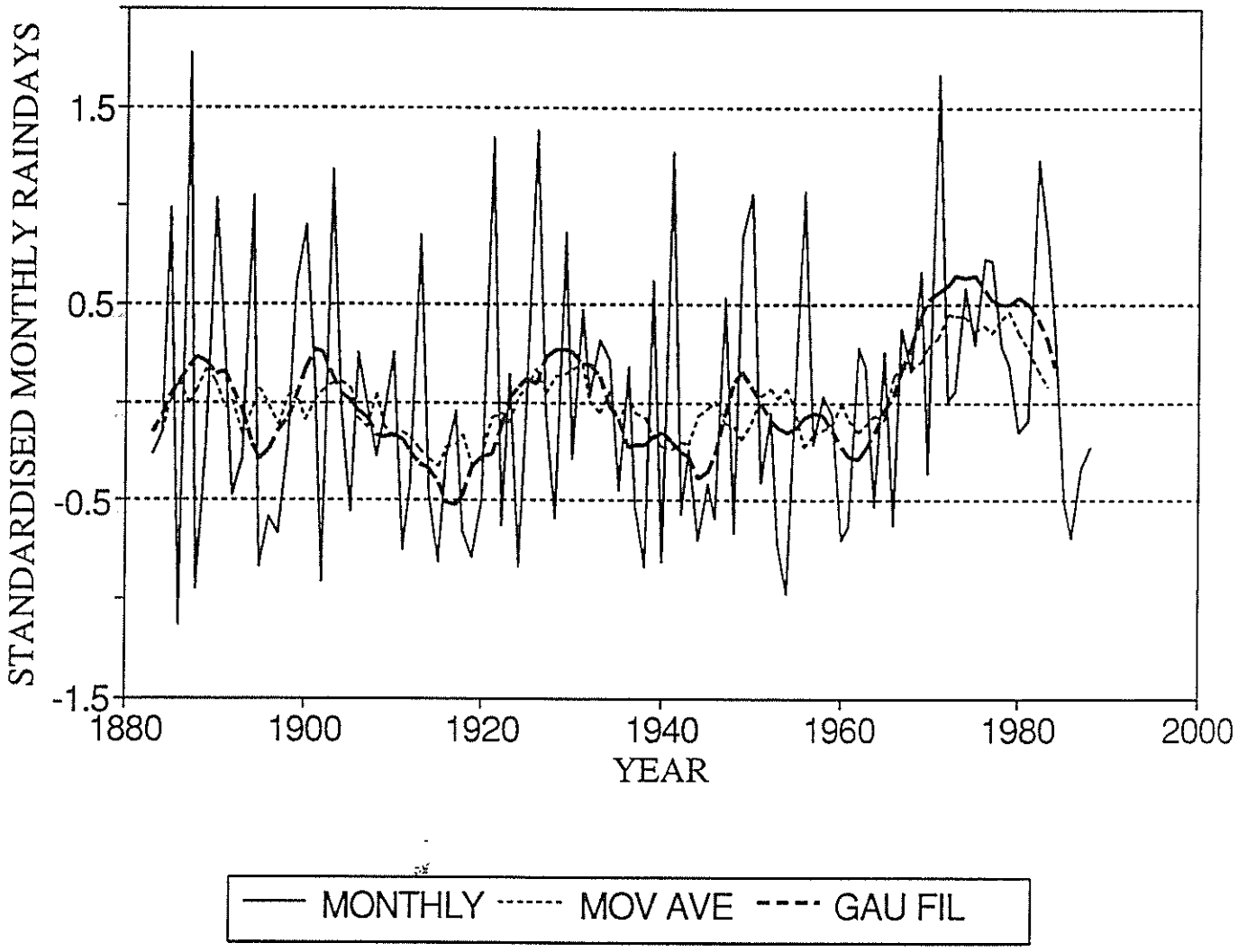


Fig C47. Plot of March raindays time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

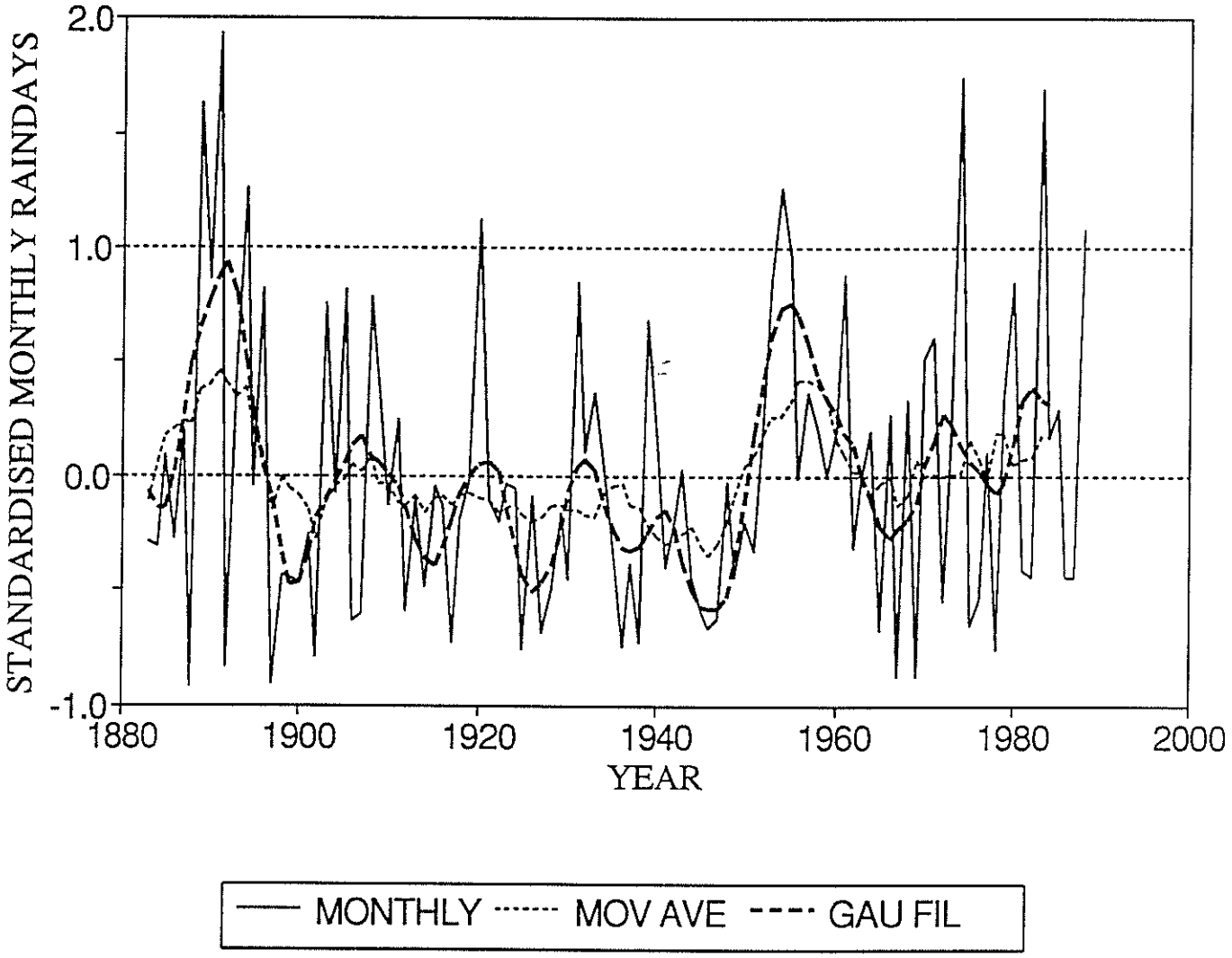


Fig C48. Plot of April raindays time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

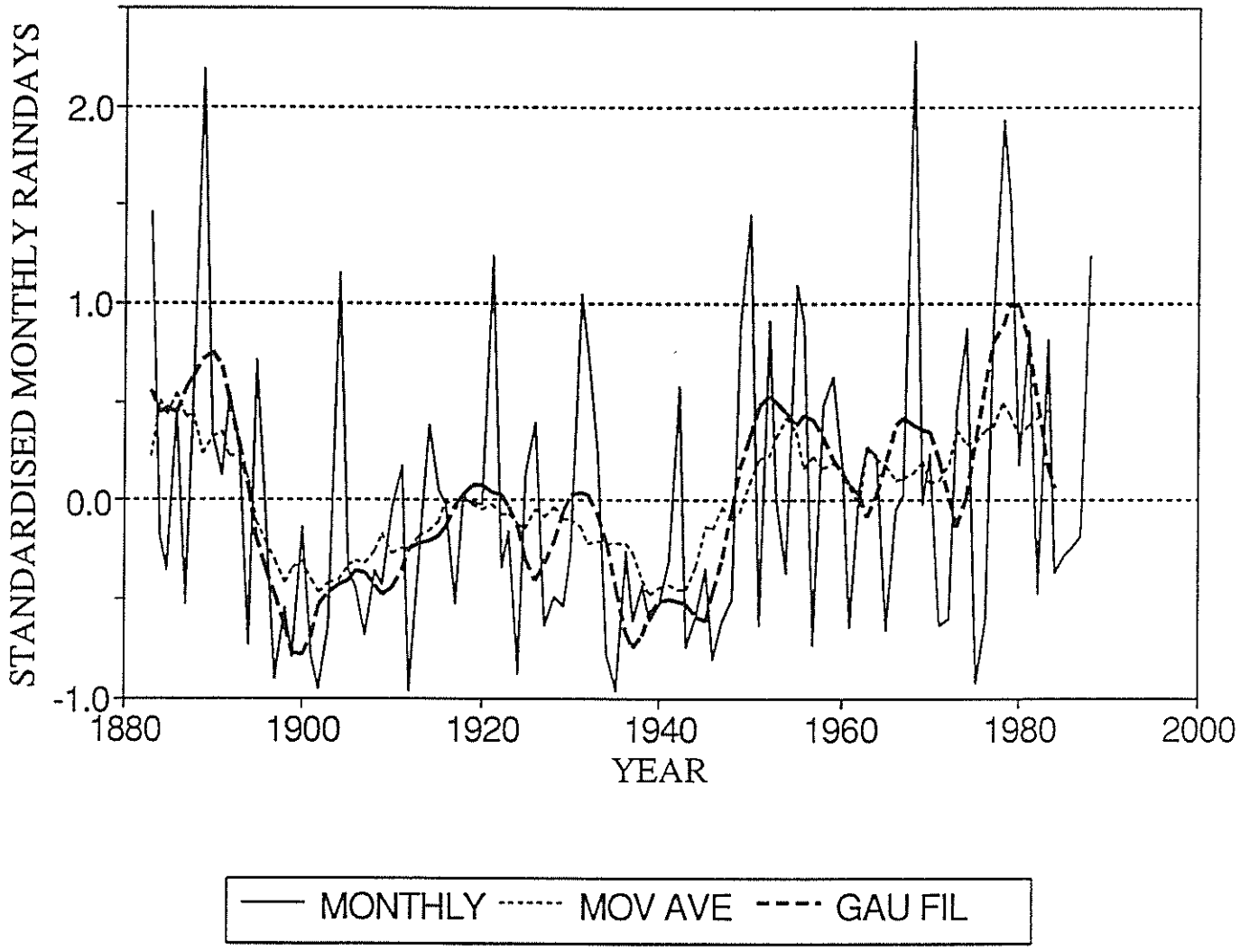


Fig C49. Plot of May raindays time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

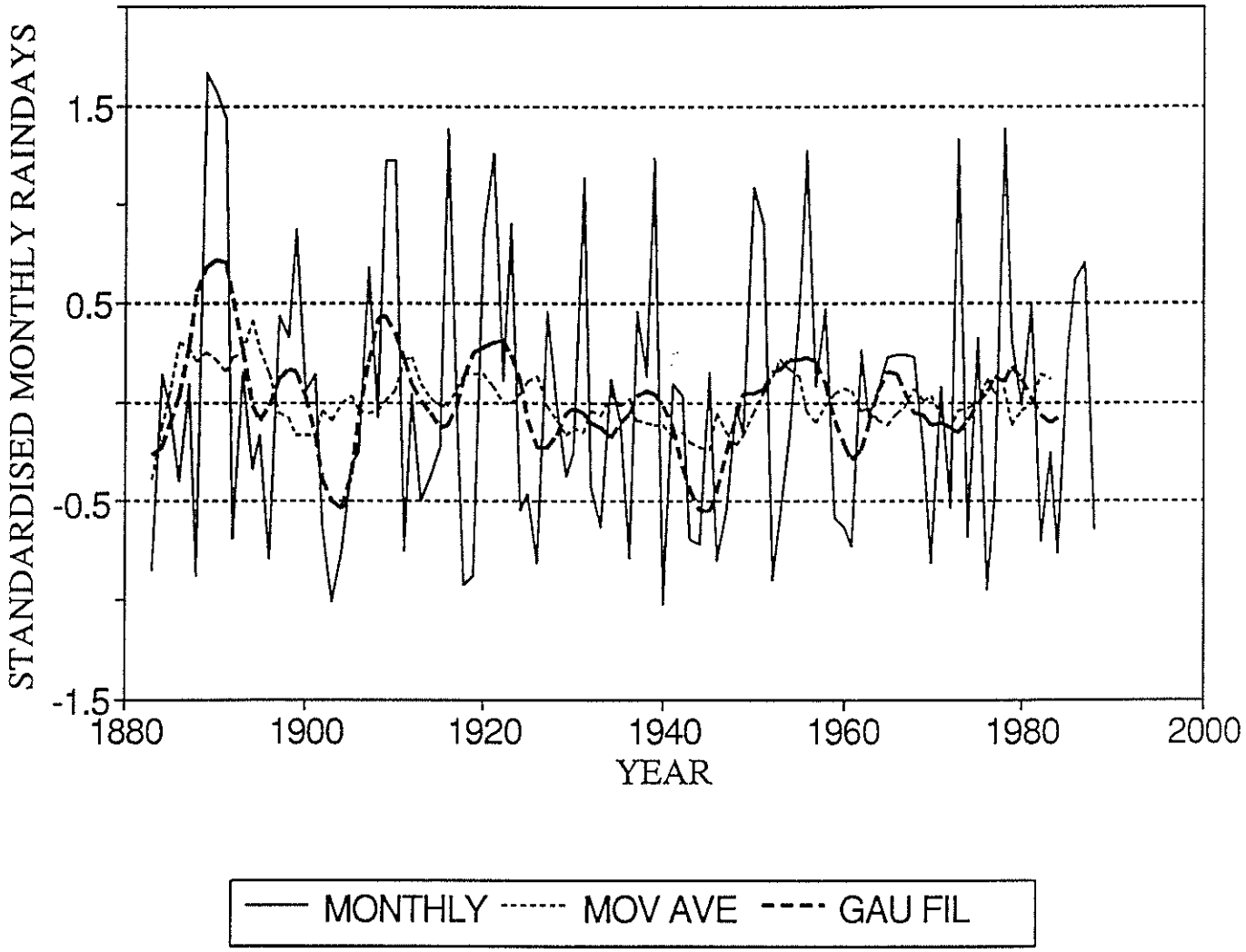


Fig C50. Plot of June raindays time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

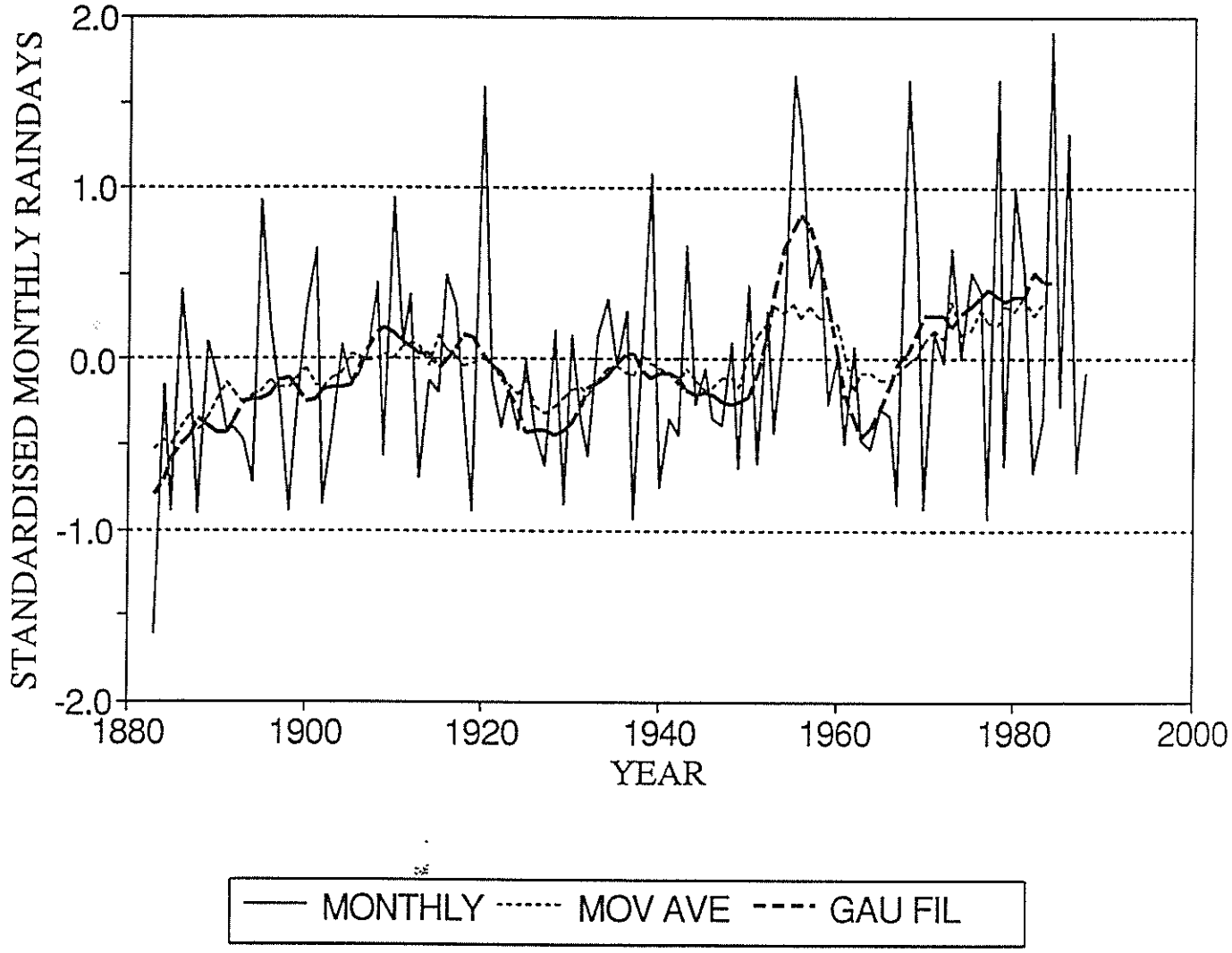


Fig C51. Plot of July raindays time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

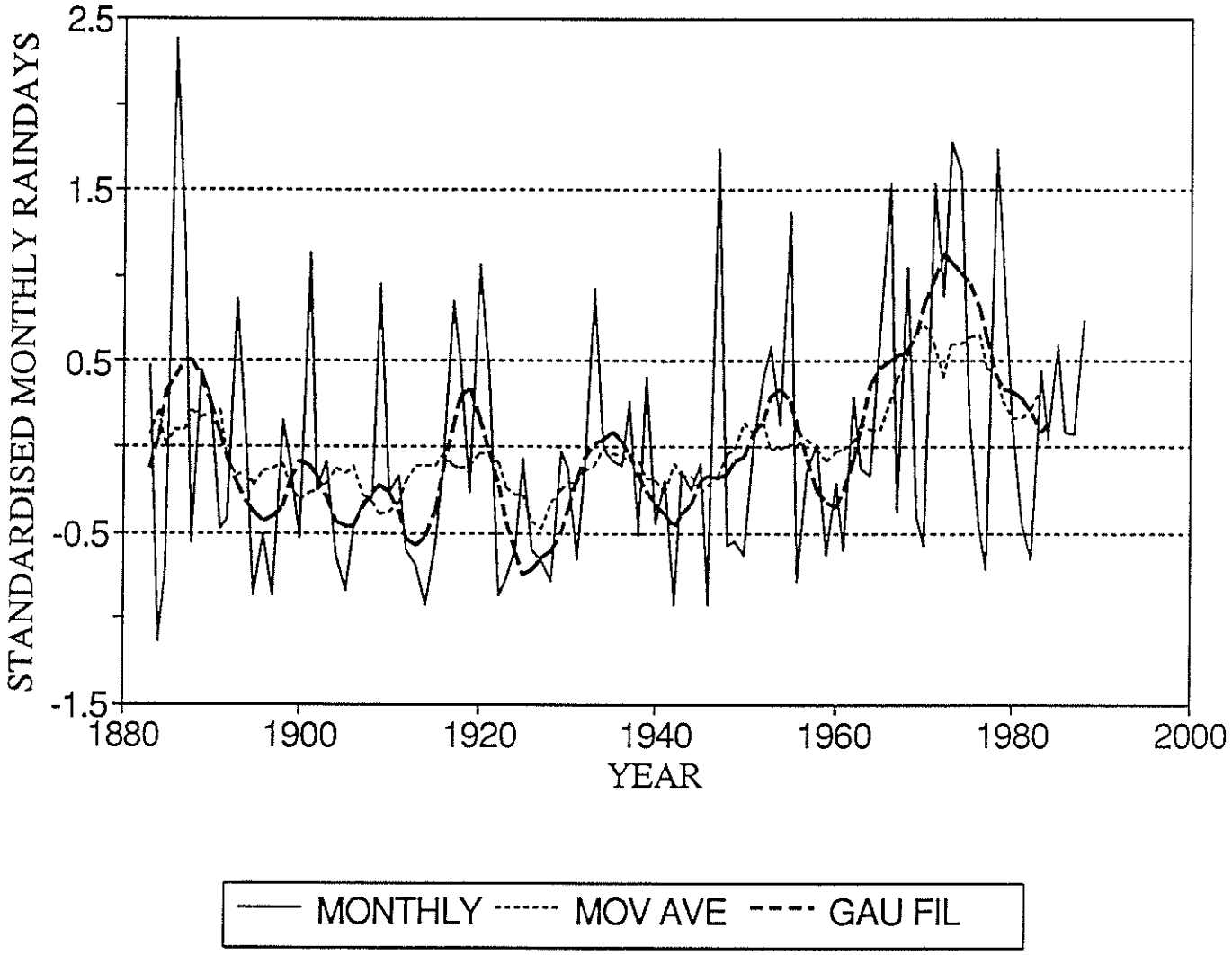


Fig C52. Plot of August raindays time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

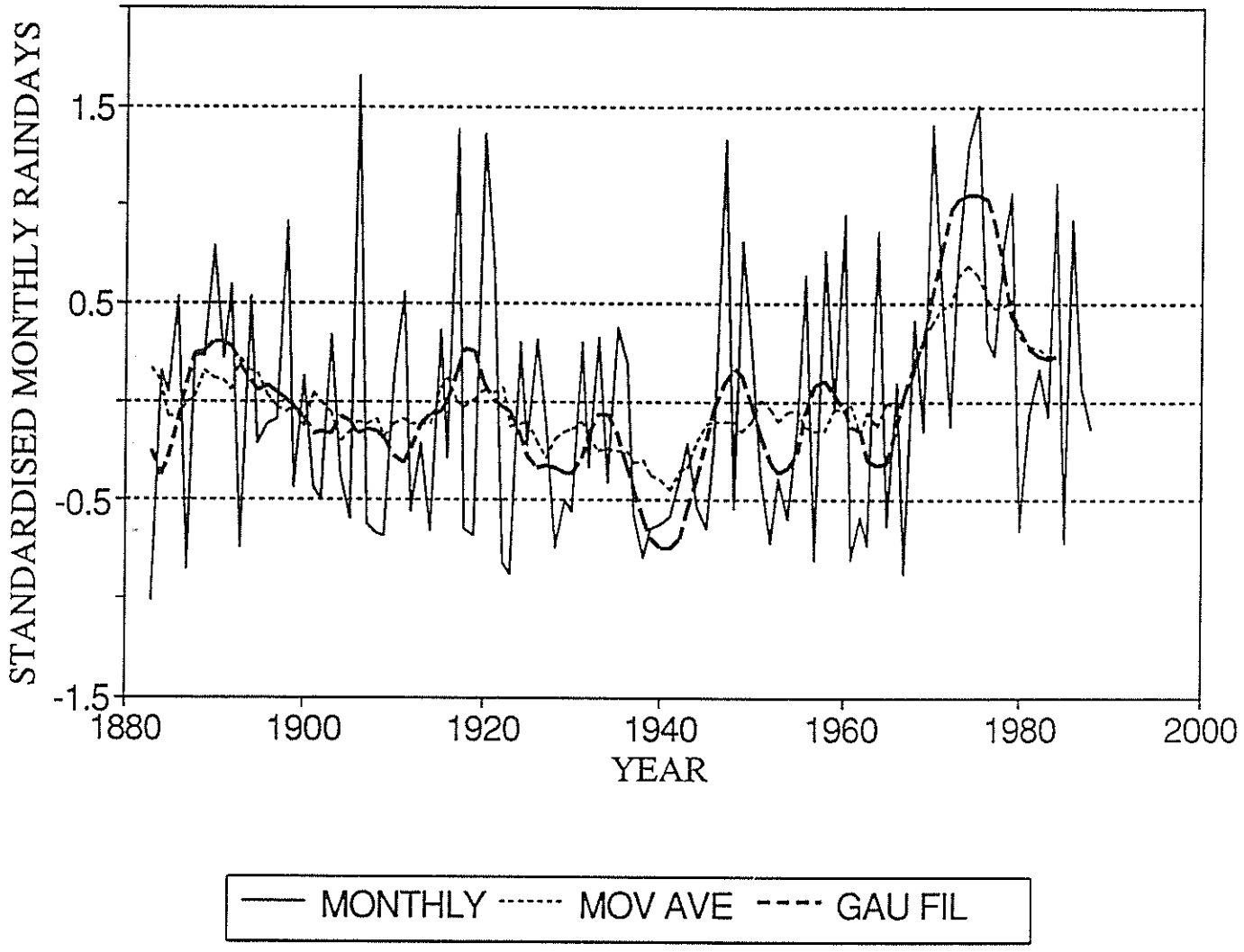


Fig C53. Plot of September raindays time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

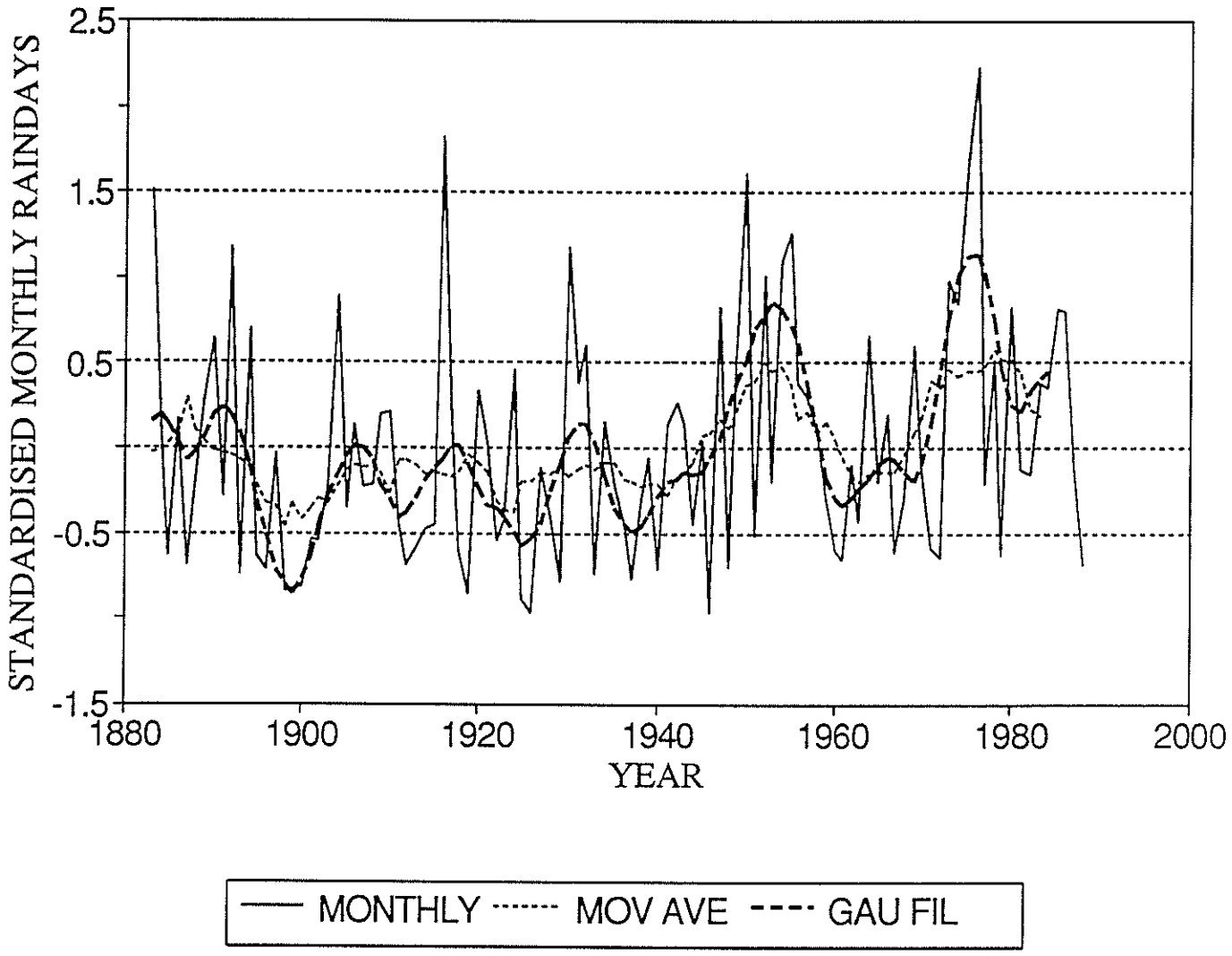


Fig C54. Plot of October raindays time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

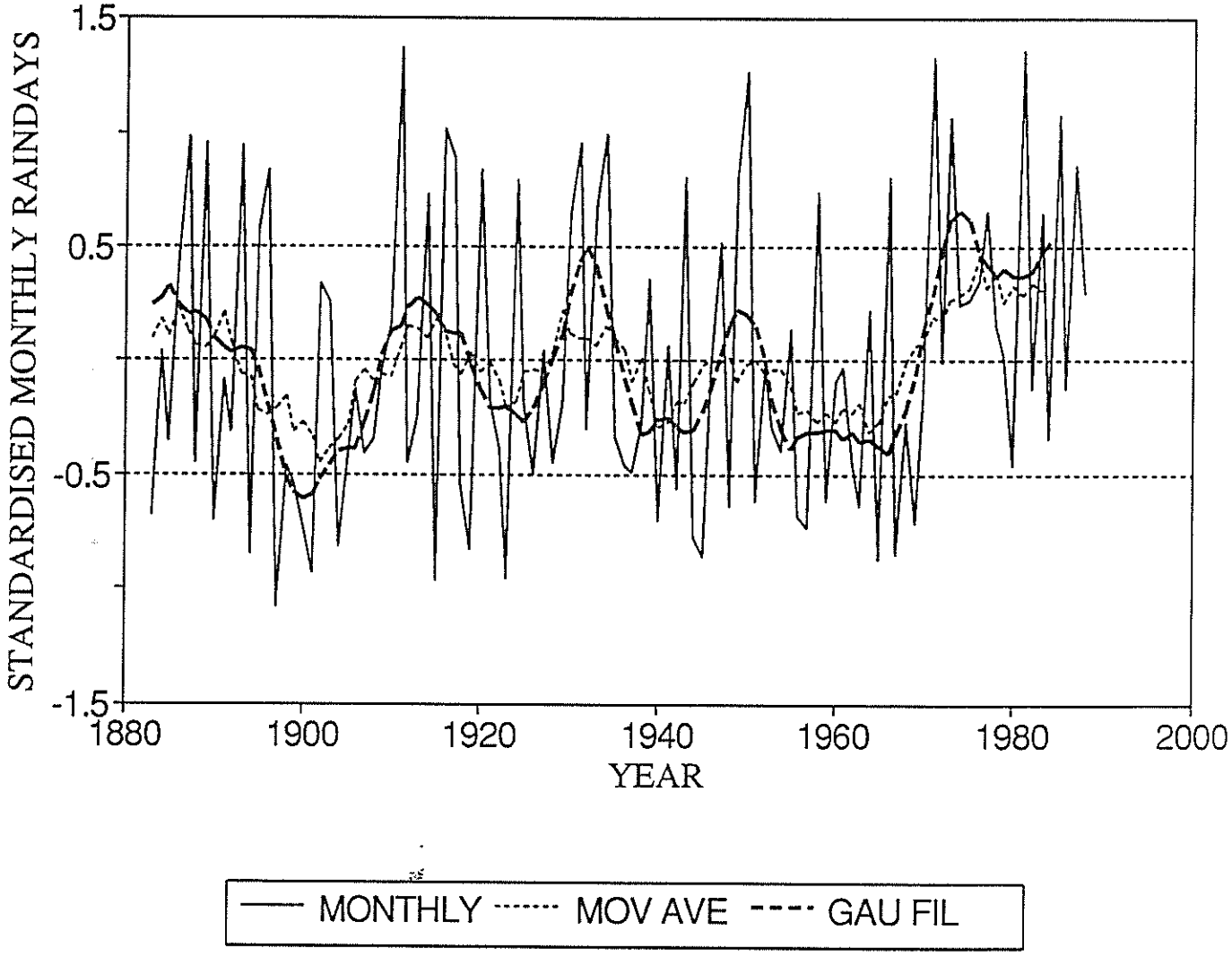


Fig C55. Plot of November raindays time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

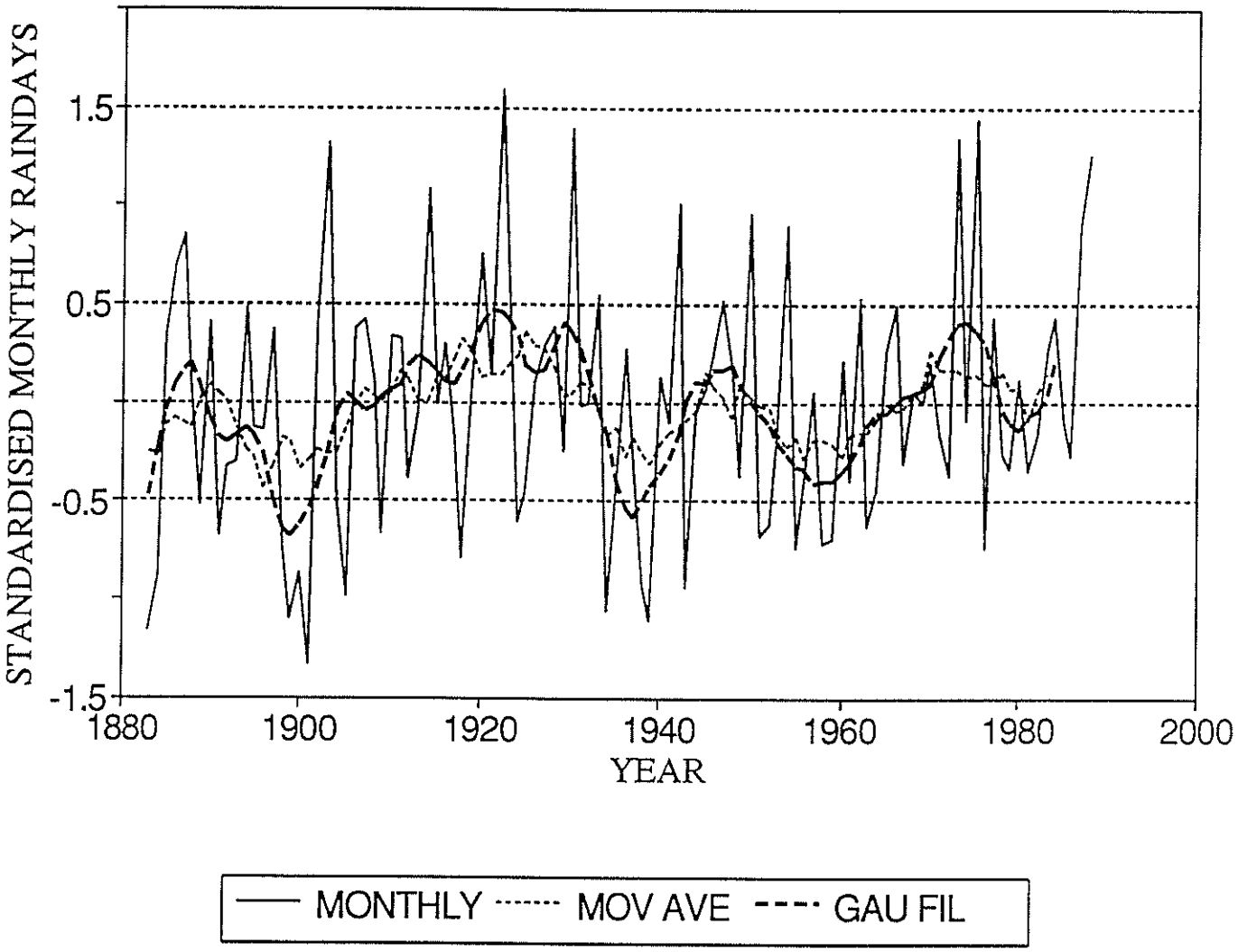


Fig C56. Plot of December raindays time series with 11 year moving average and 11 point Gaussian filter for arid (mainly summer) region.

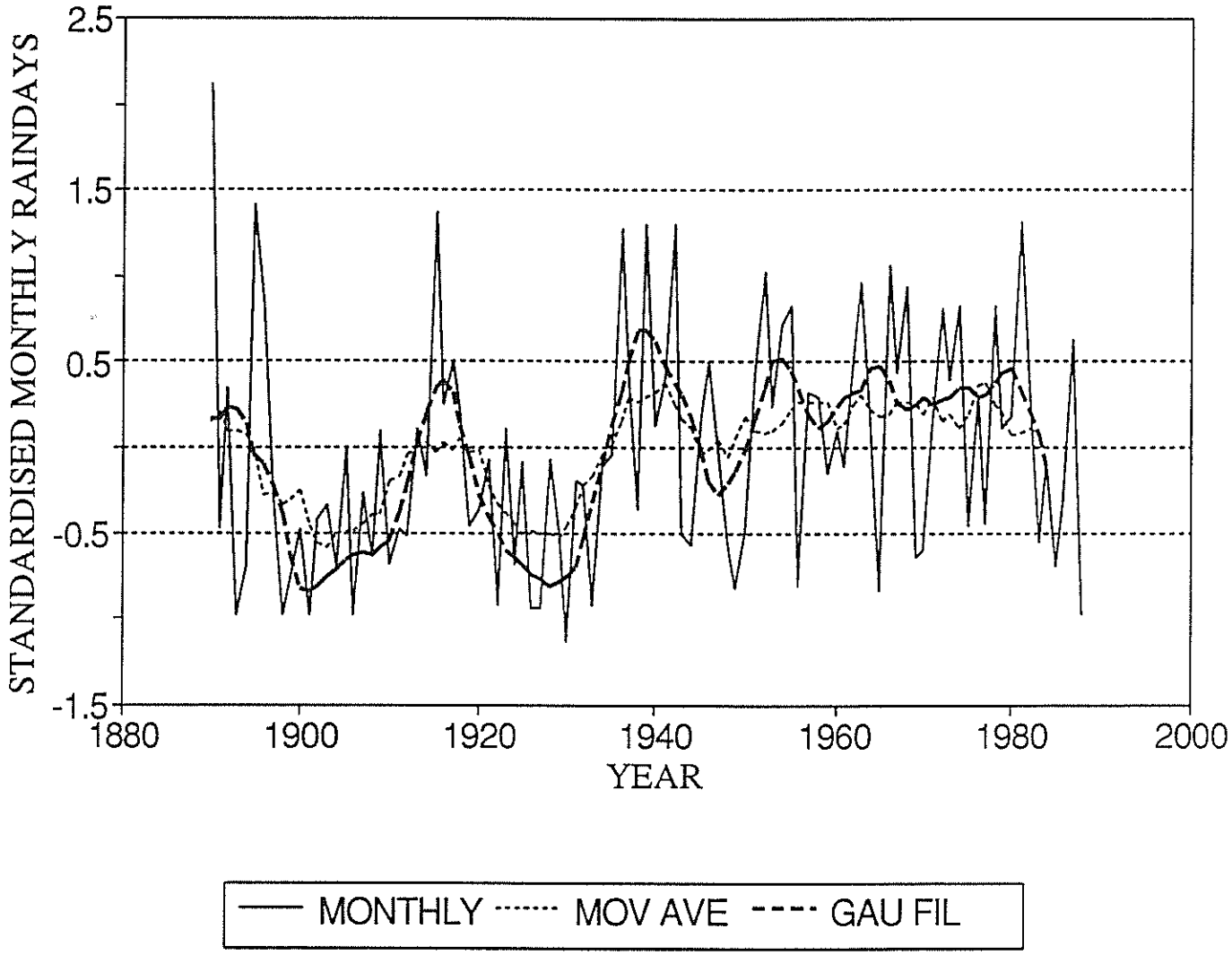


Fig C57. Plot of January raindays time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

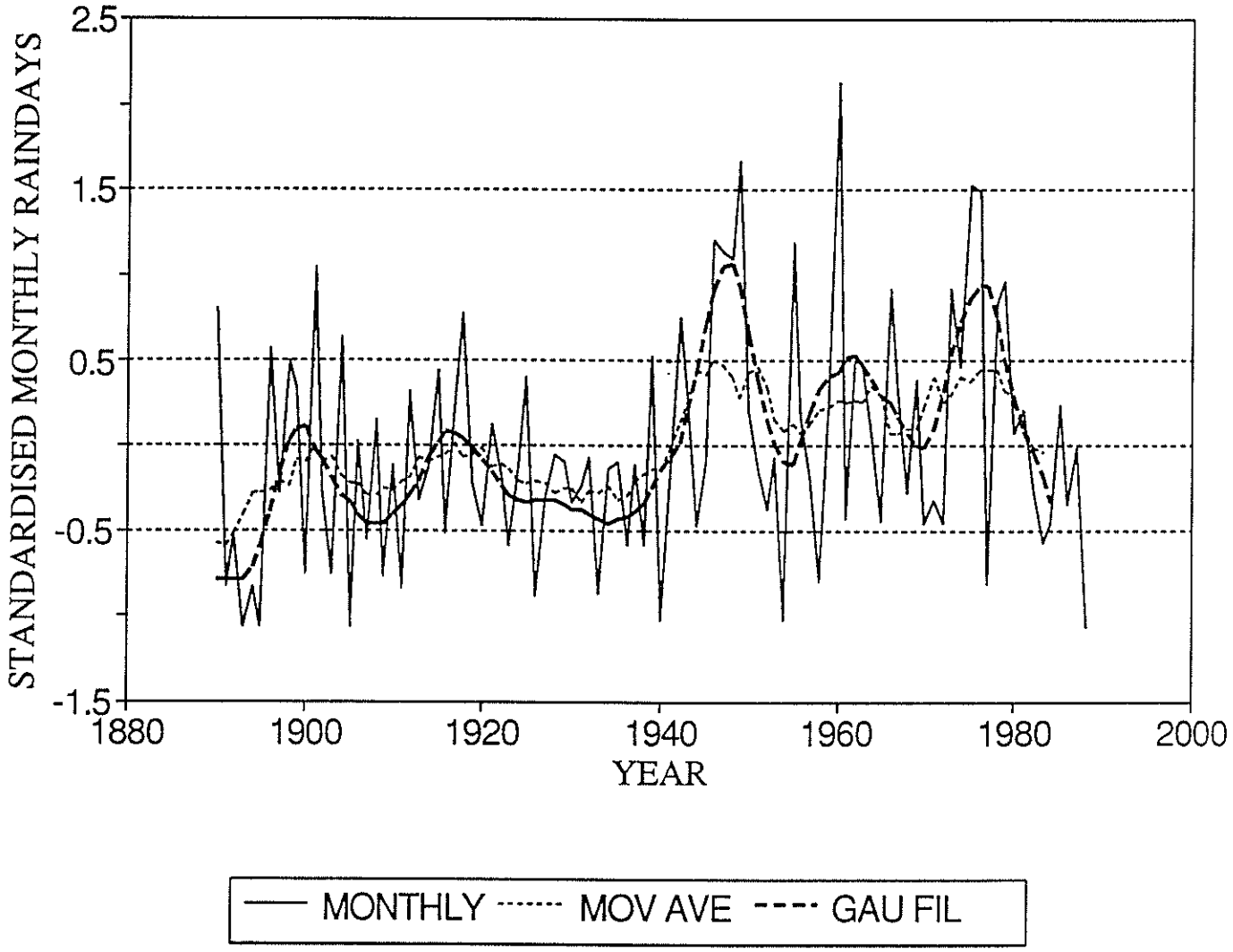


Fig C58. Plot of February raindays time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

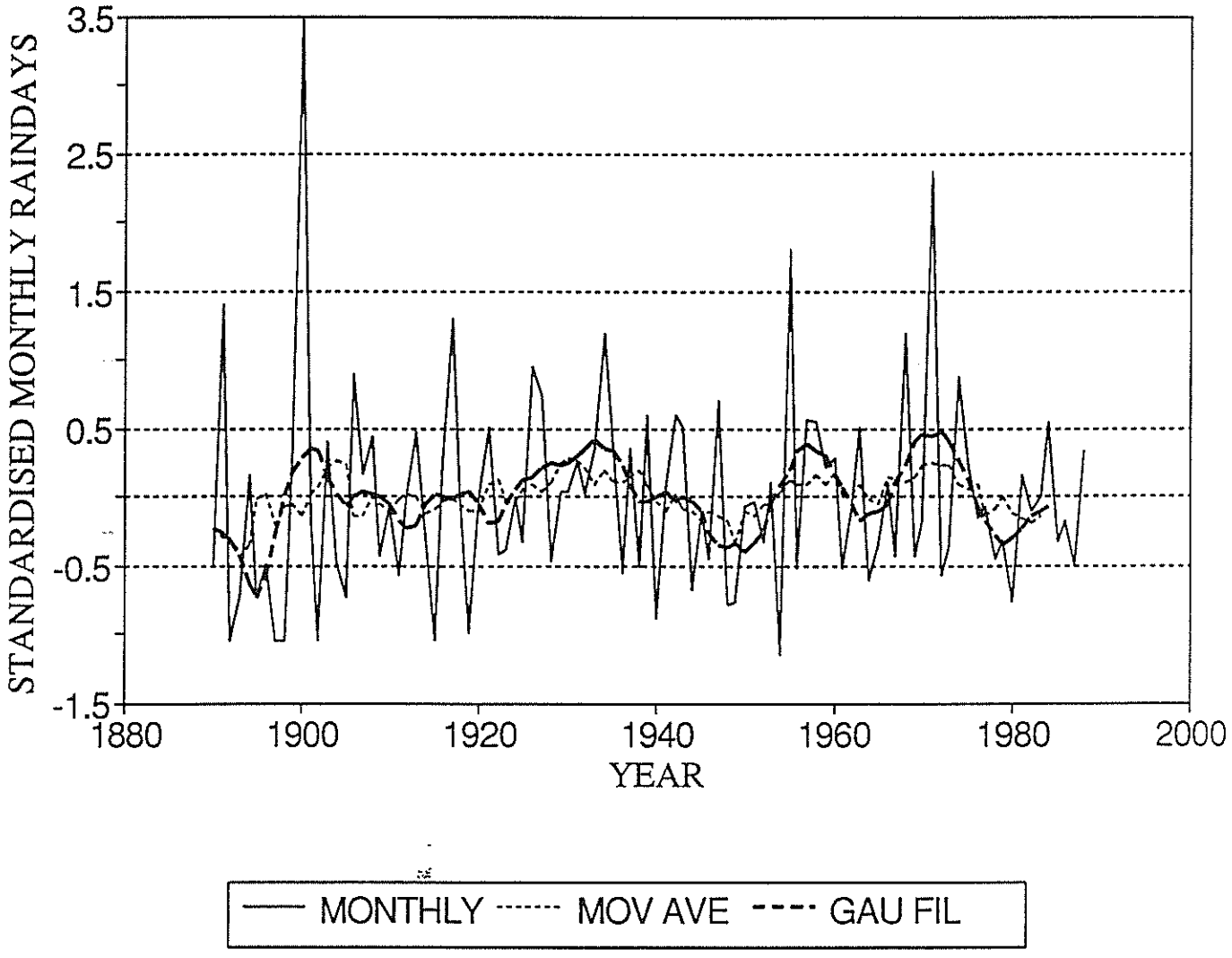


Fig C59. Plot of March raindays time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

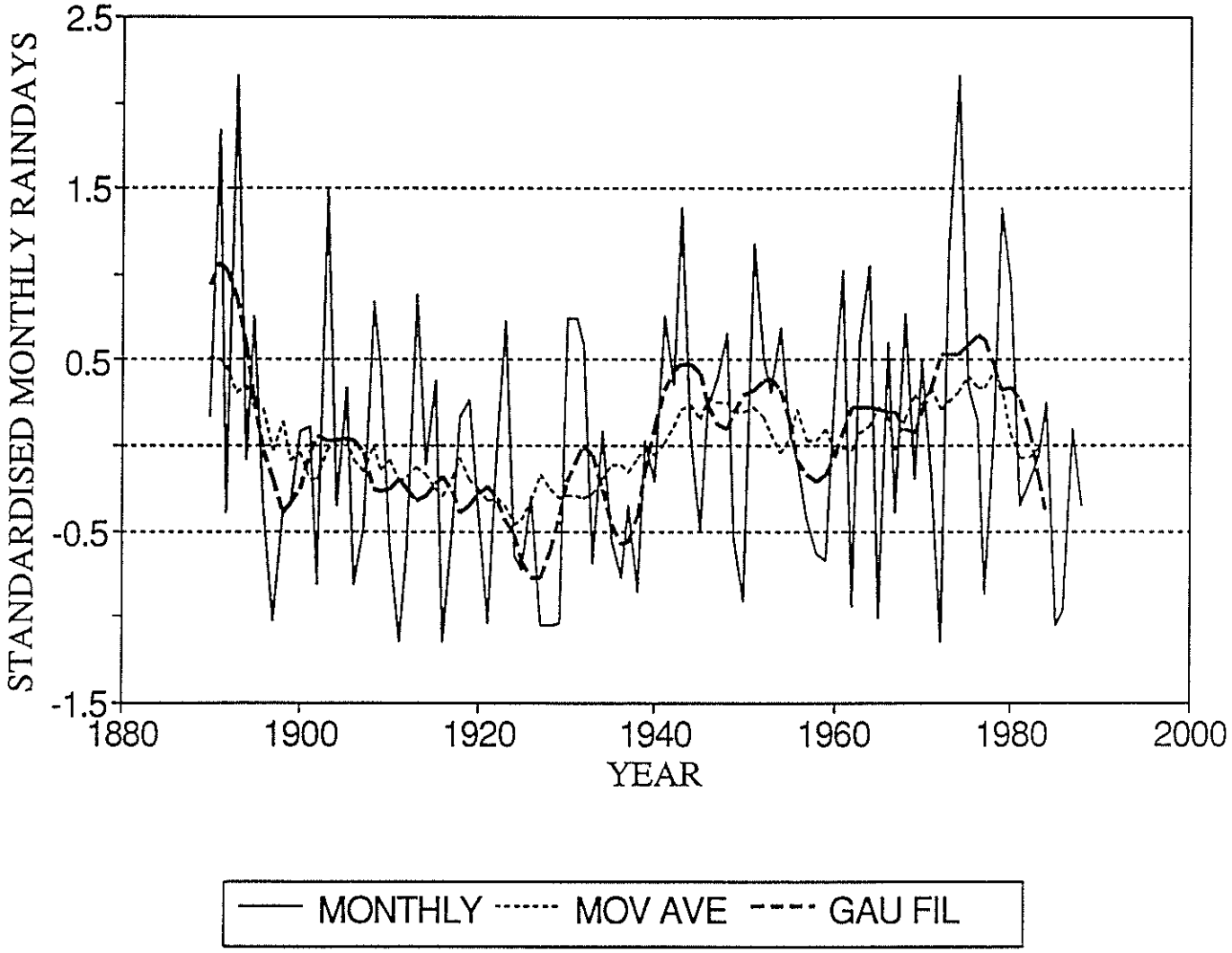


Fig C60. Plot of April raindays time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

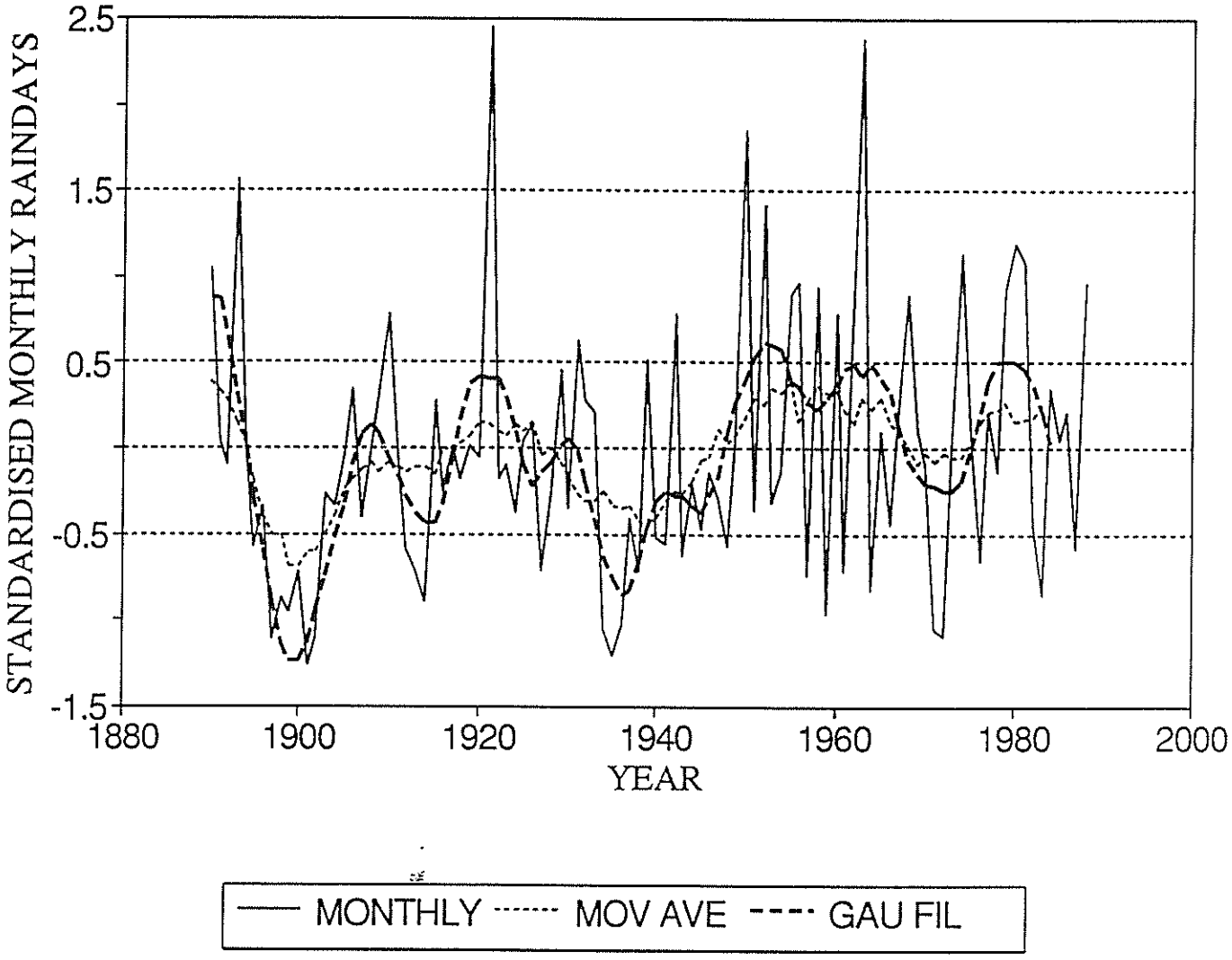


Fig C61. Plot of May raindays time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

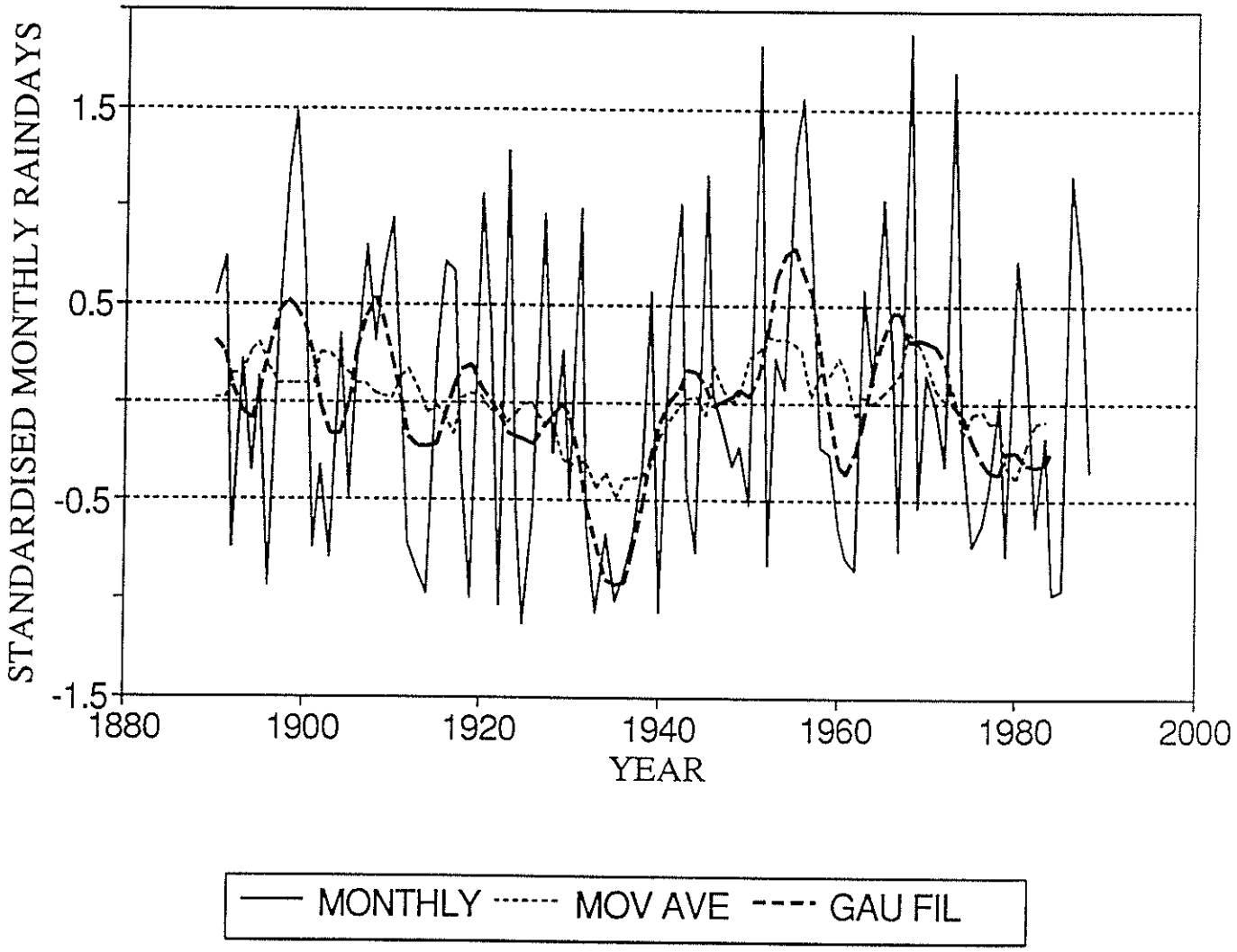


Fig C62. Plot of June raindays time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

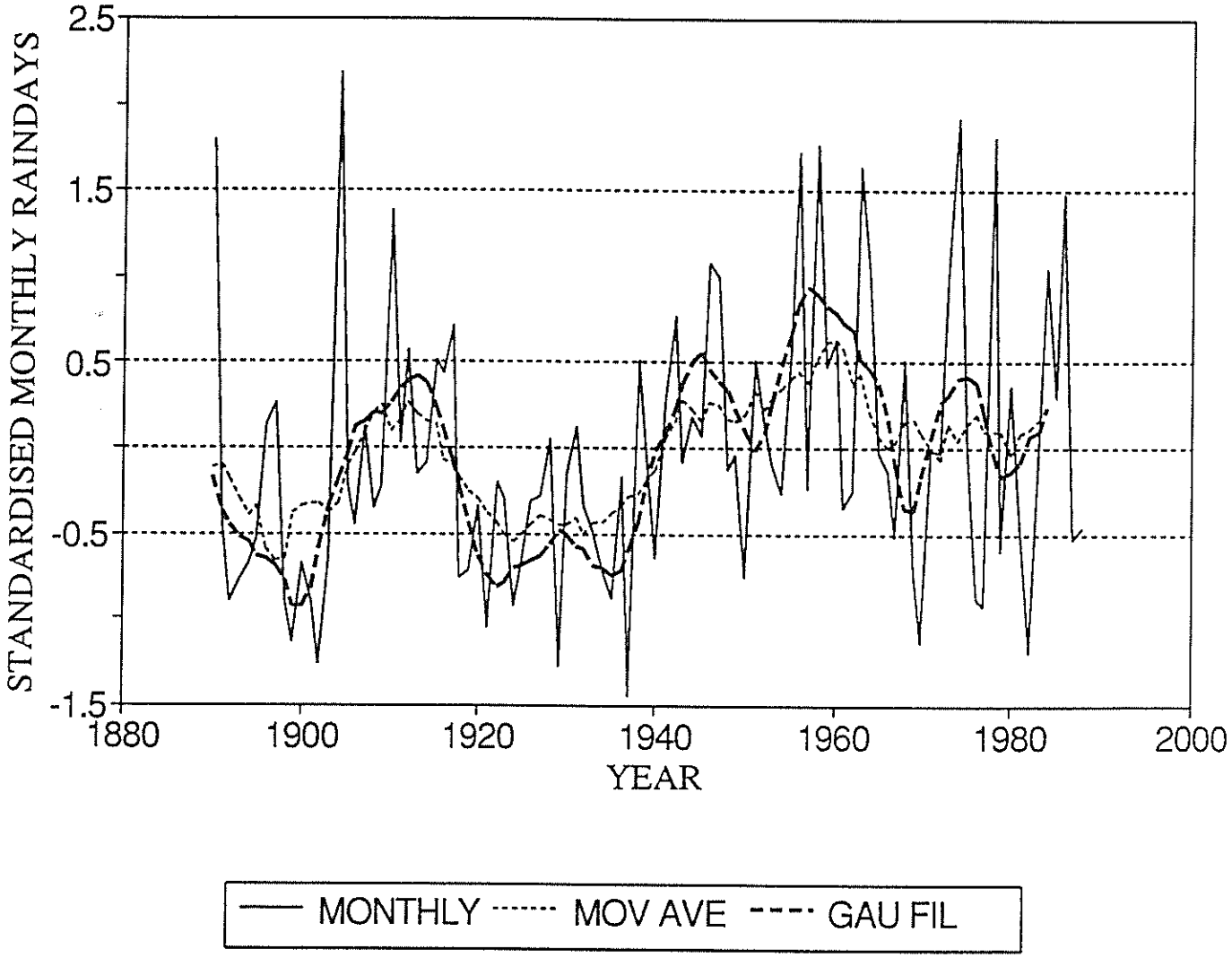


Fig C63. Plot of July raindays time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

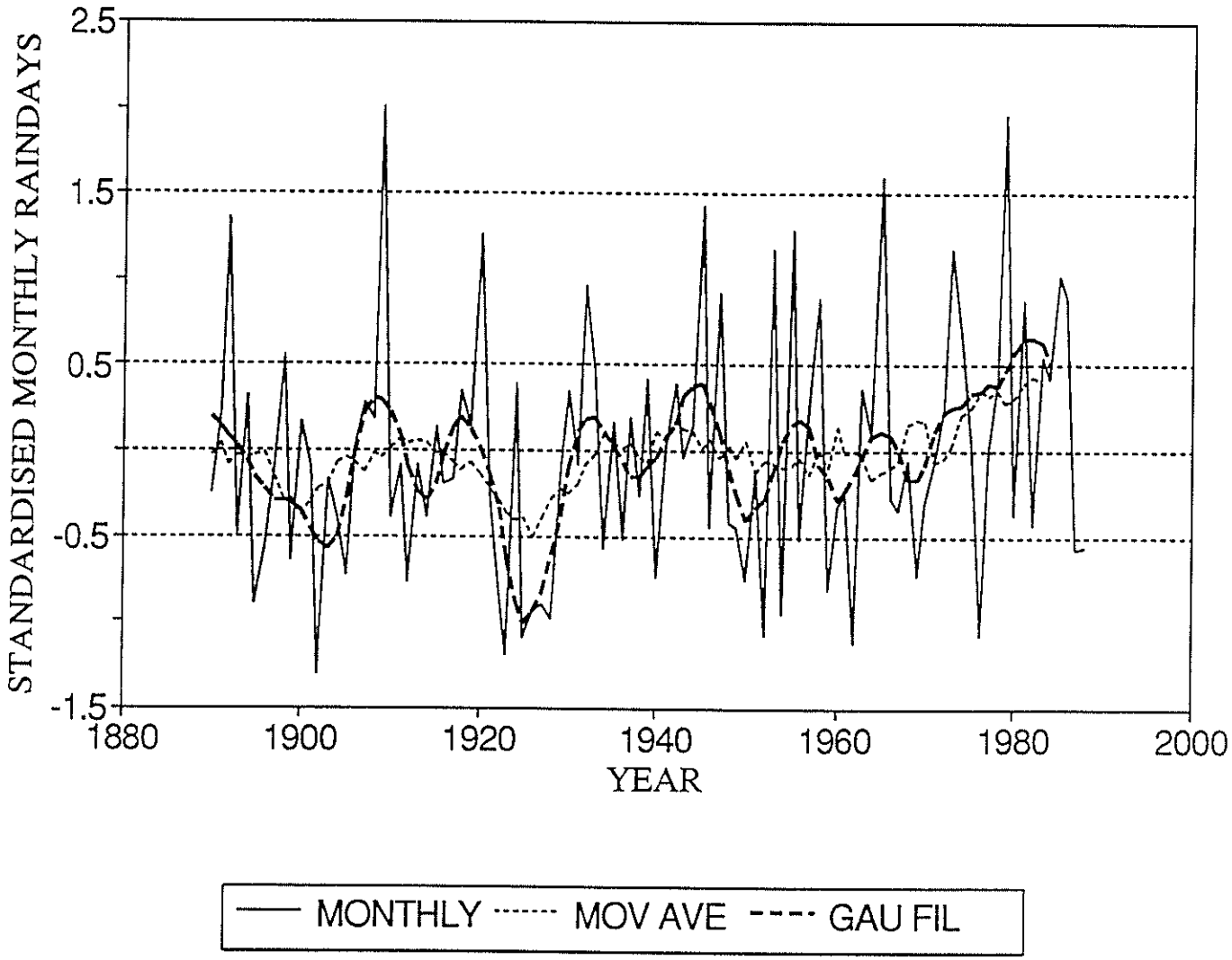


Fig C64. Plot of August raindays time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

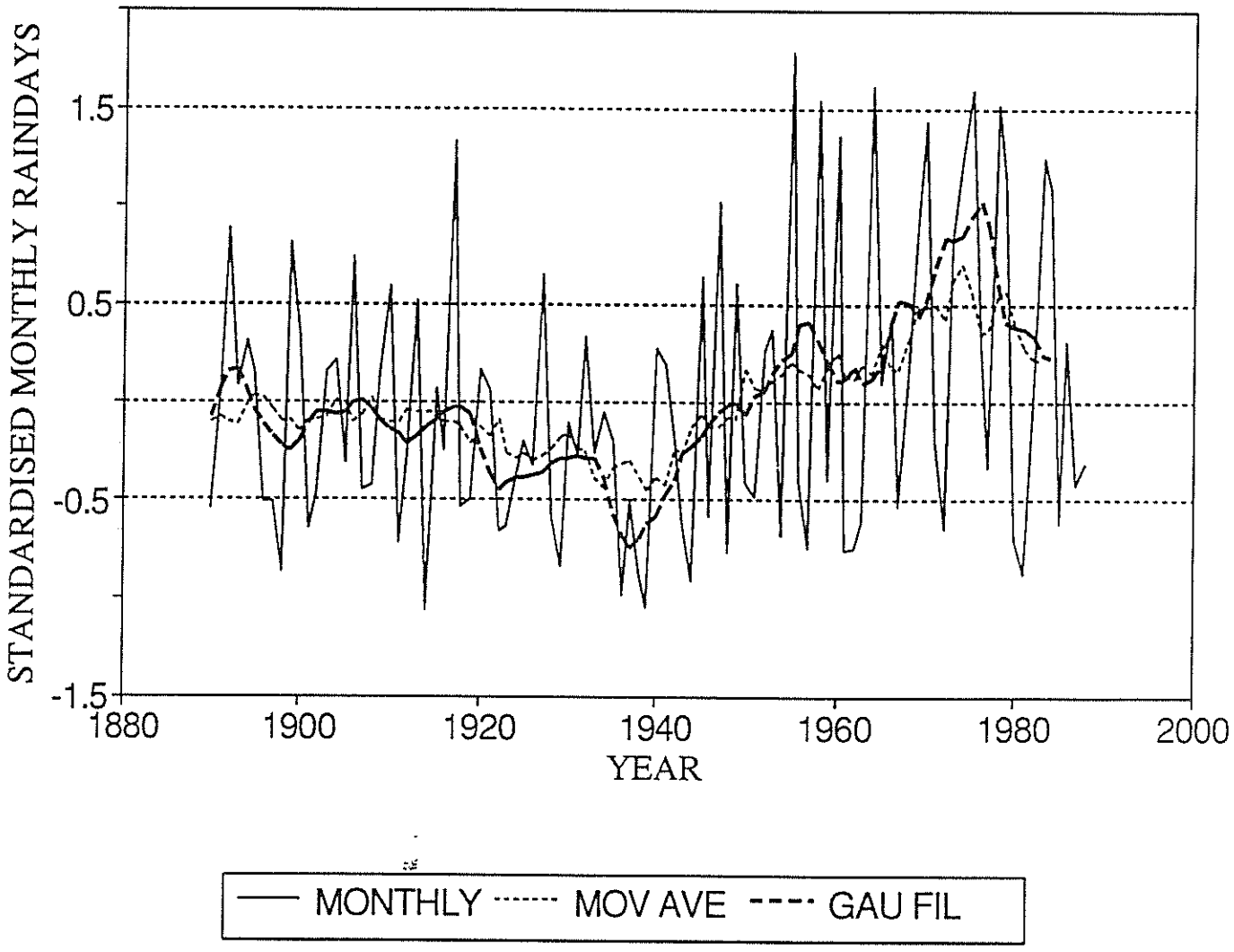


Fig C65. Plot of September raindays time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

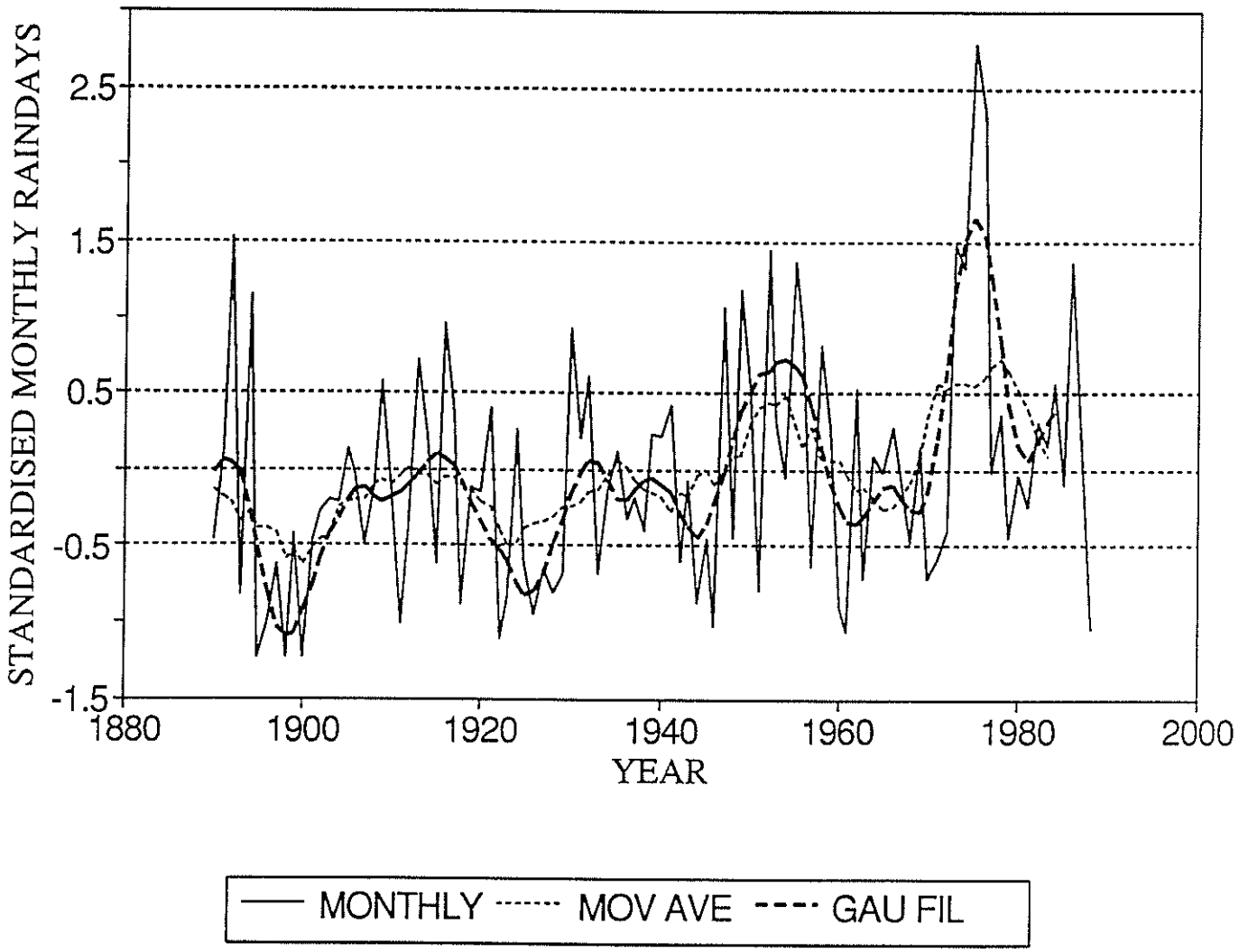


Fig C66. Plot of October raindays time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

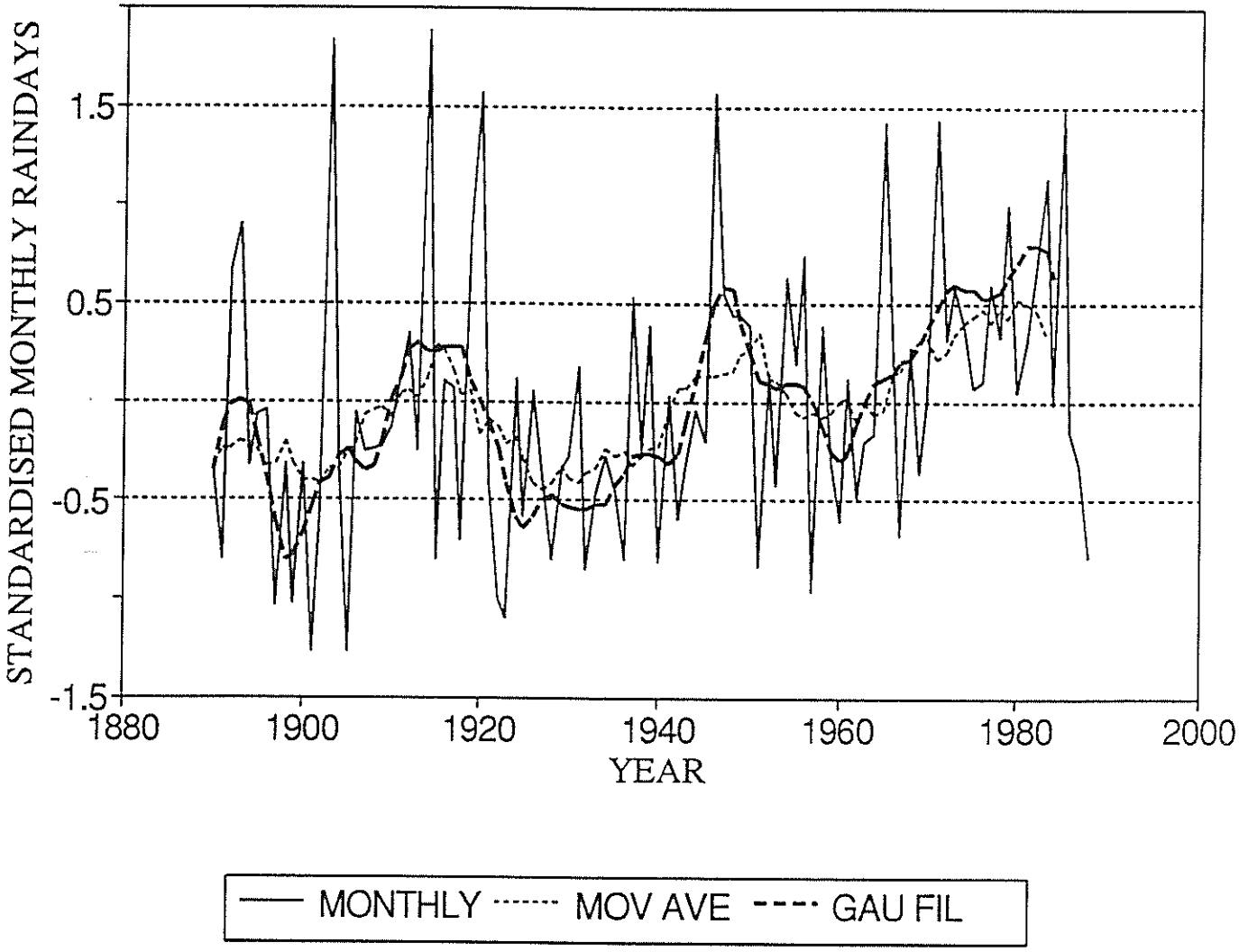


Fig C67. Plot of November raindays time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

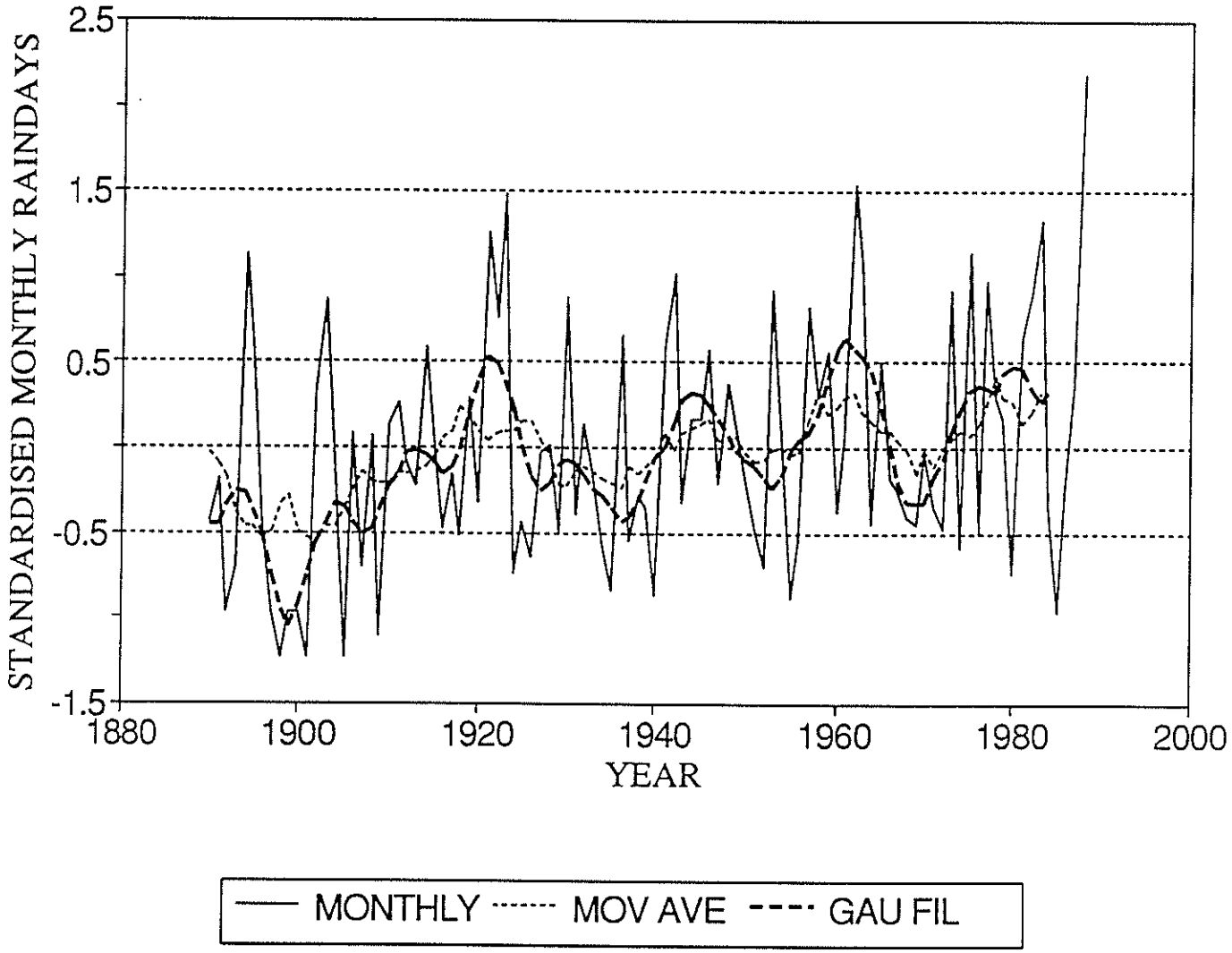


Fig C68. Plot of December raindays time series with 11 year moving average and 11 point Gaussian filter for arid (winter/non-seasonal) region.

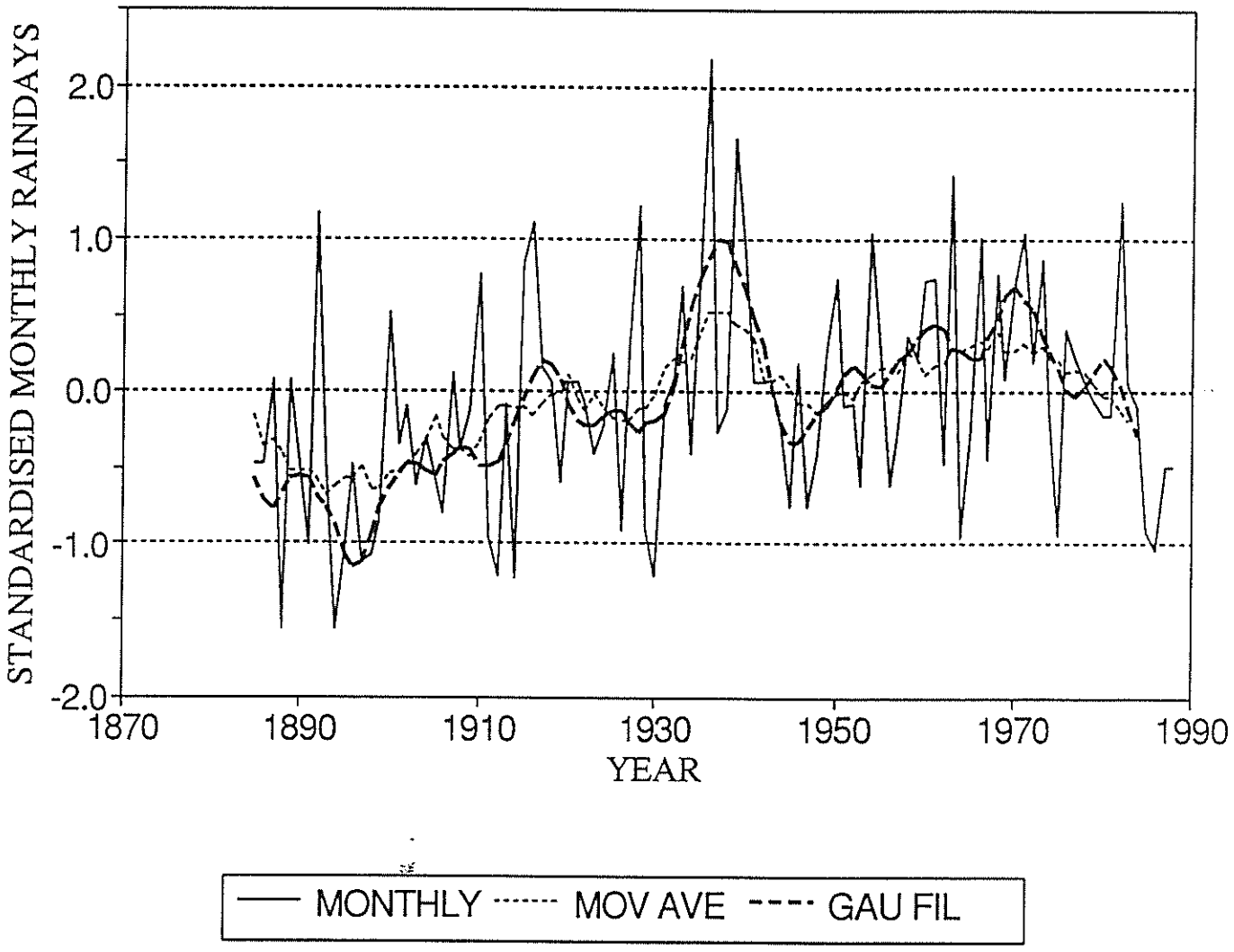


Fig C69. Plot of January raindays time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

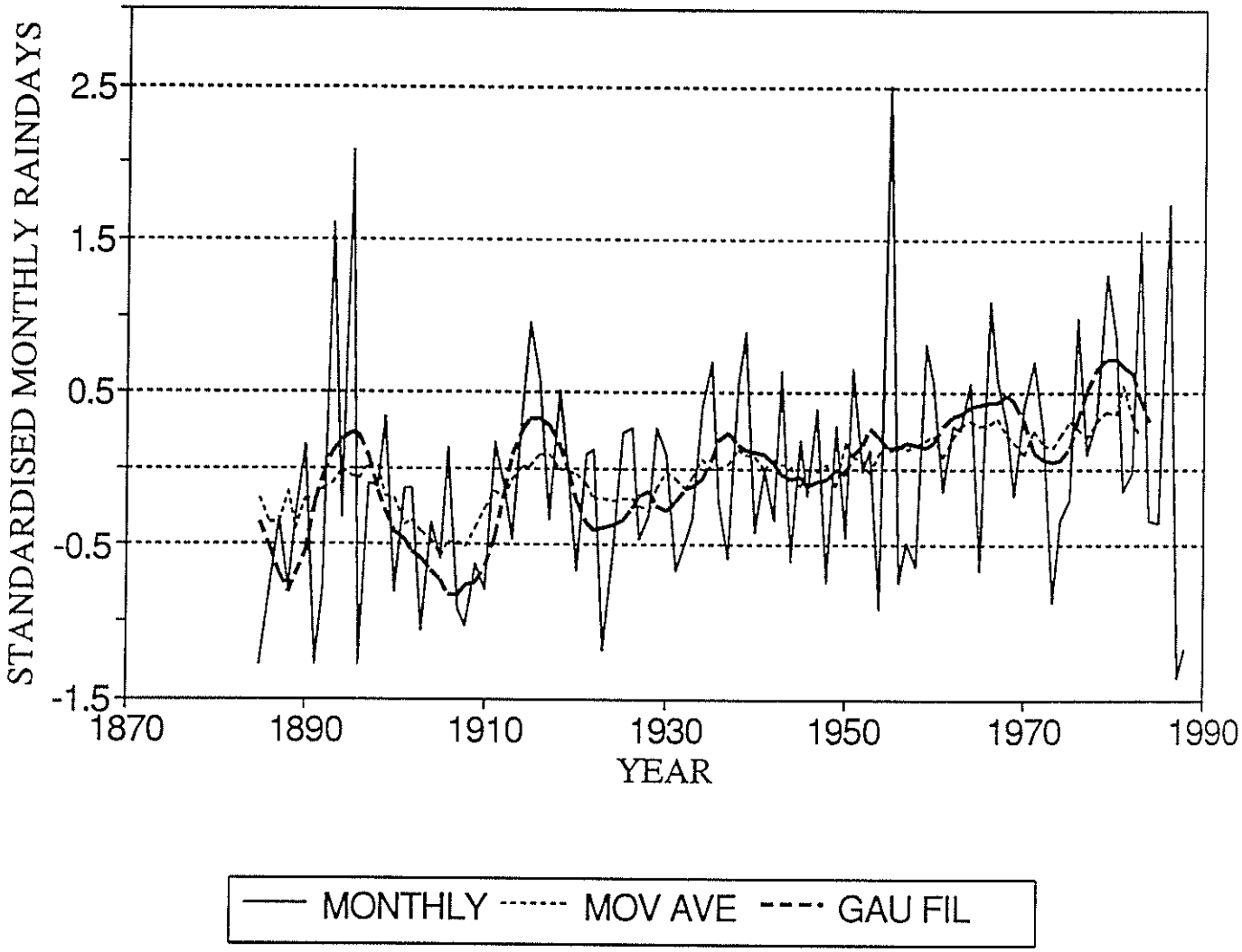


Fig C70. Plot of February raindays time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

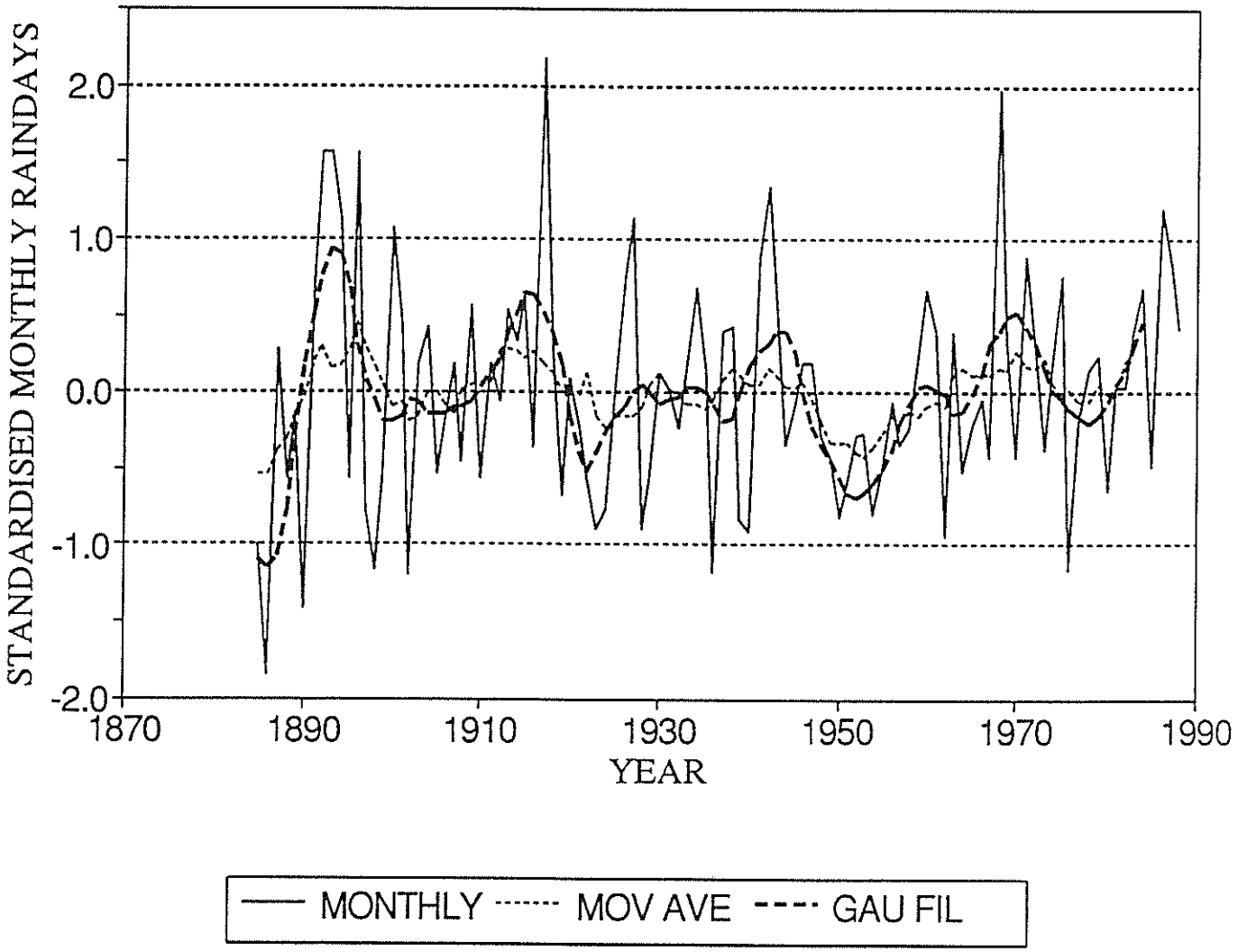


Fig C71. Plot of March raindays time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

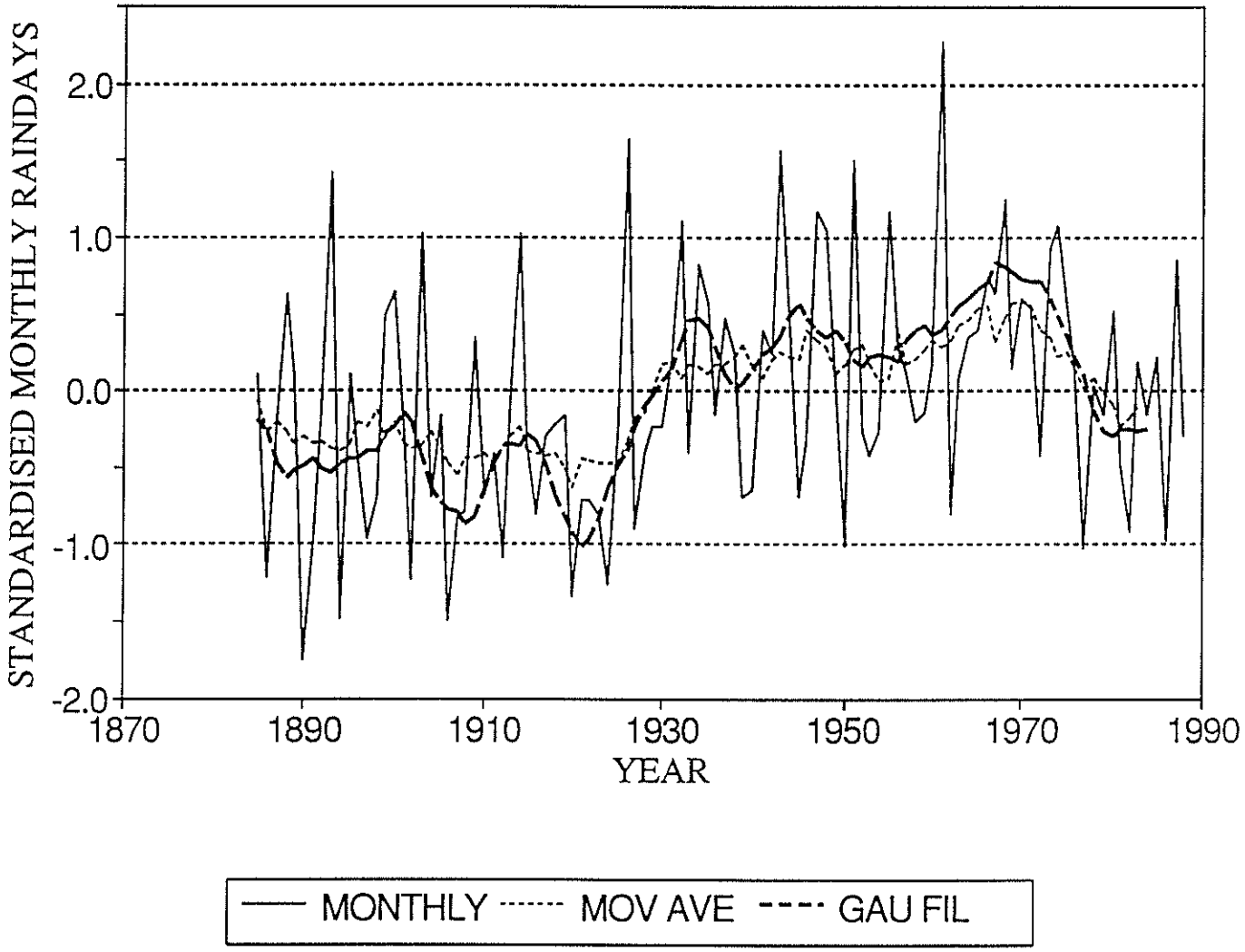


Fig C72. Plot of April raindays time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

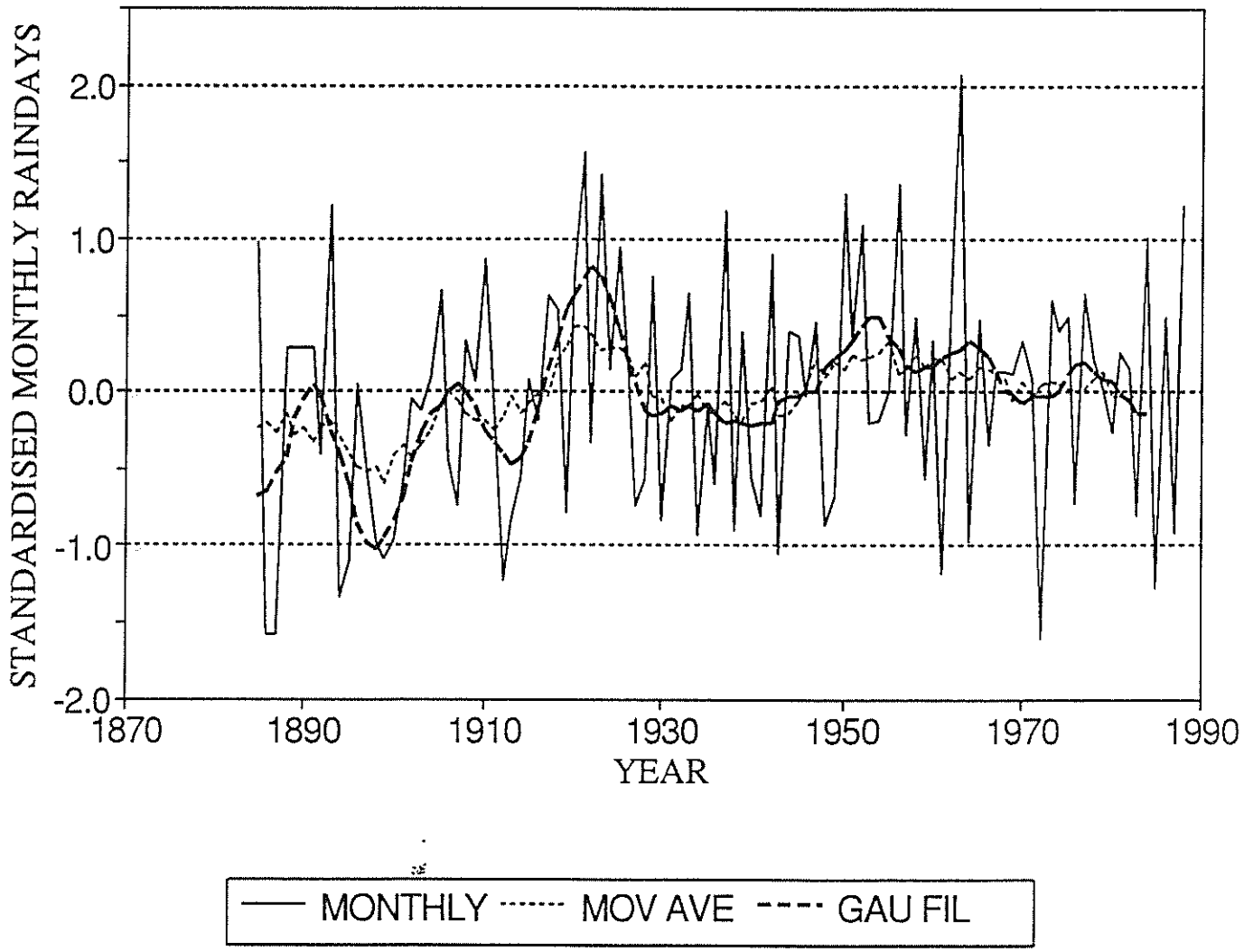


Fig C73. Plot of May raindays time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

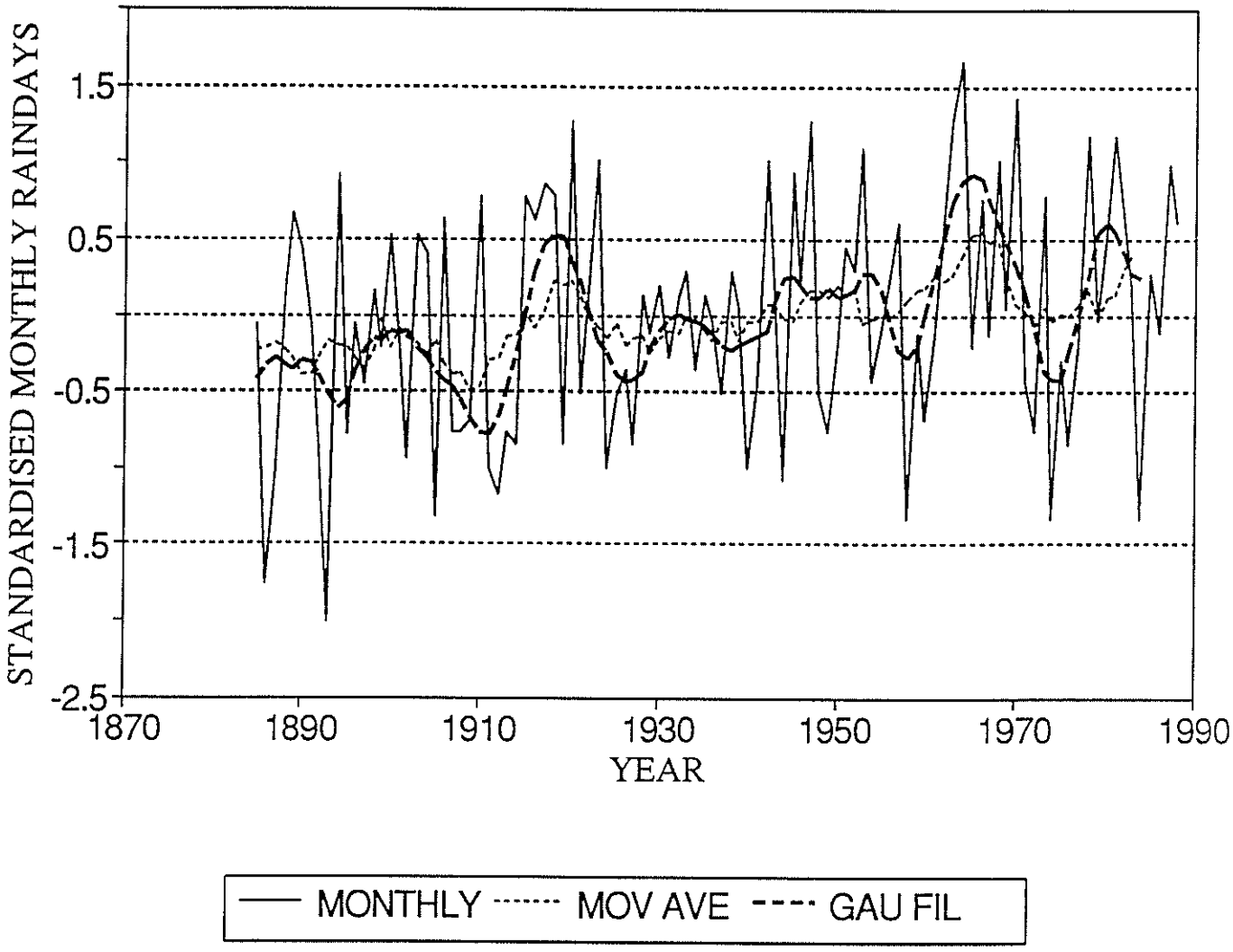


Fig C74. Plot of June raindays time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

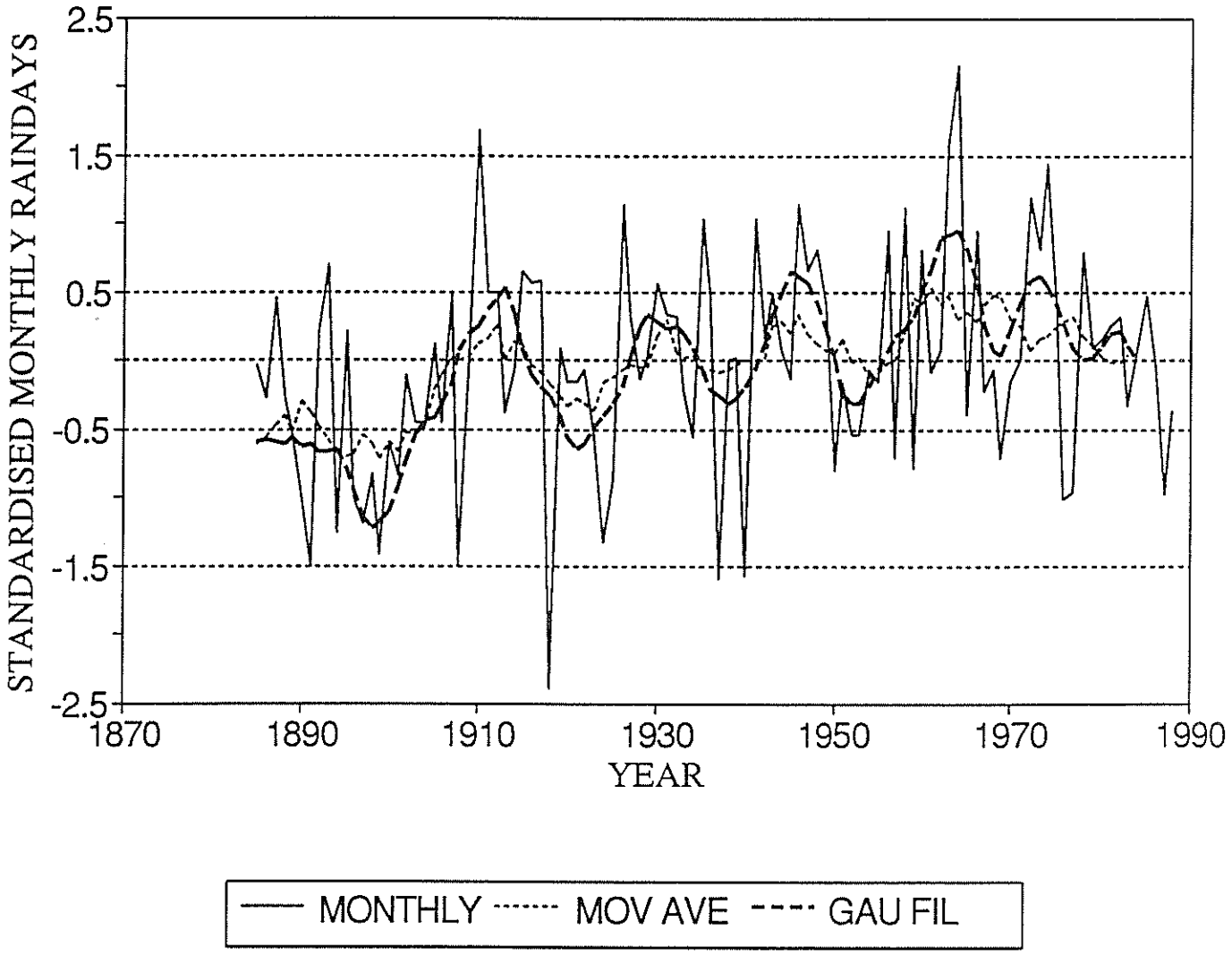


Fig C75. Plot of July raindays time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

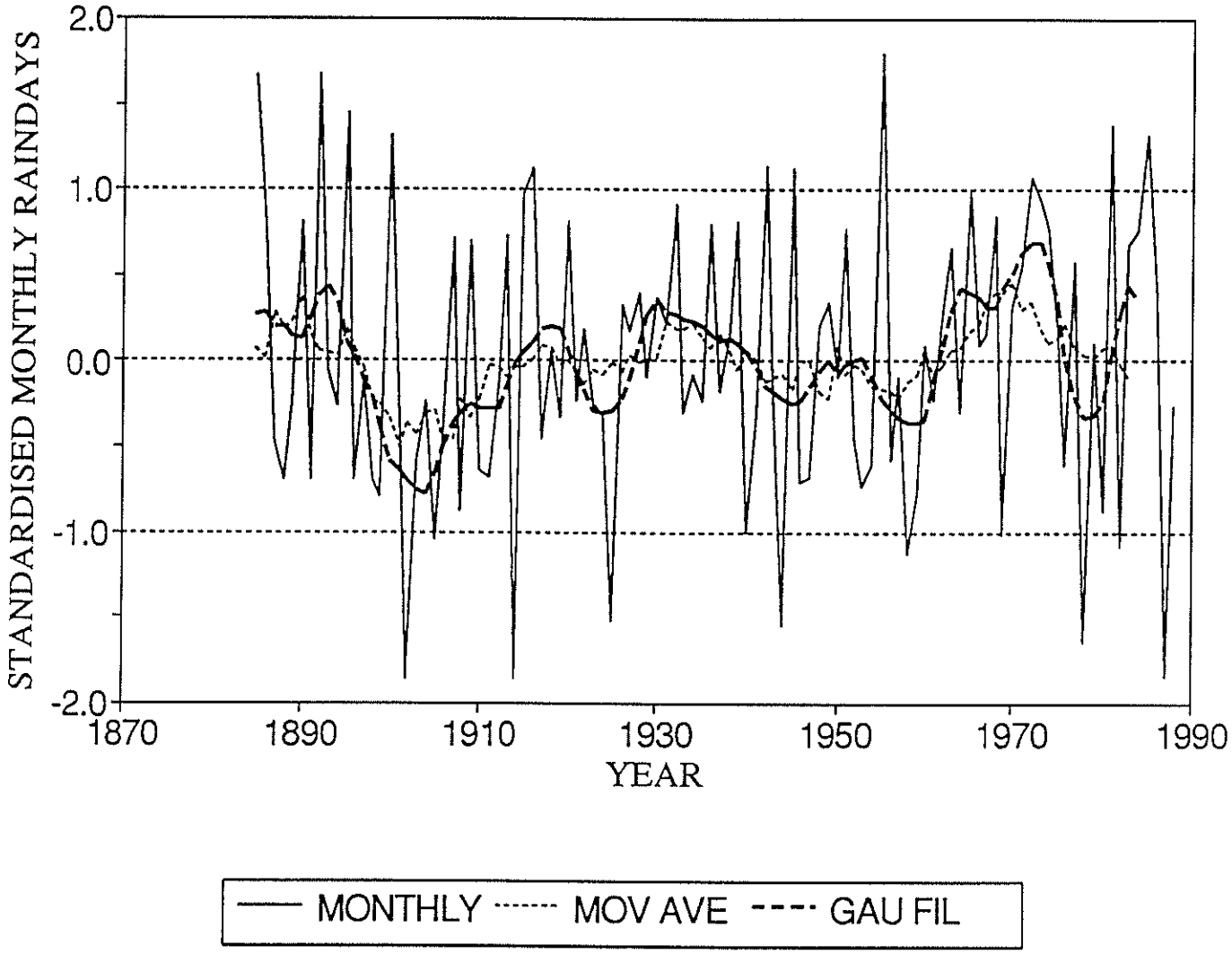


Fig C76. Plot of August raindays time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

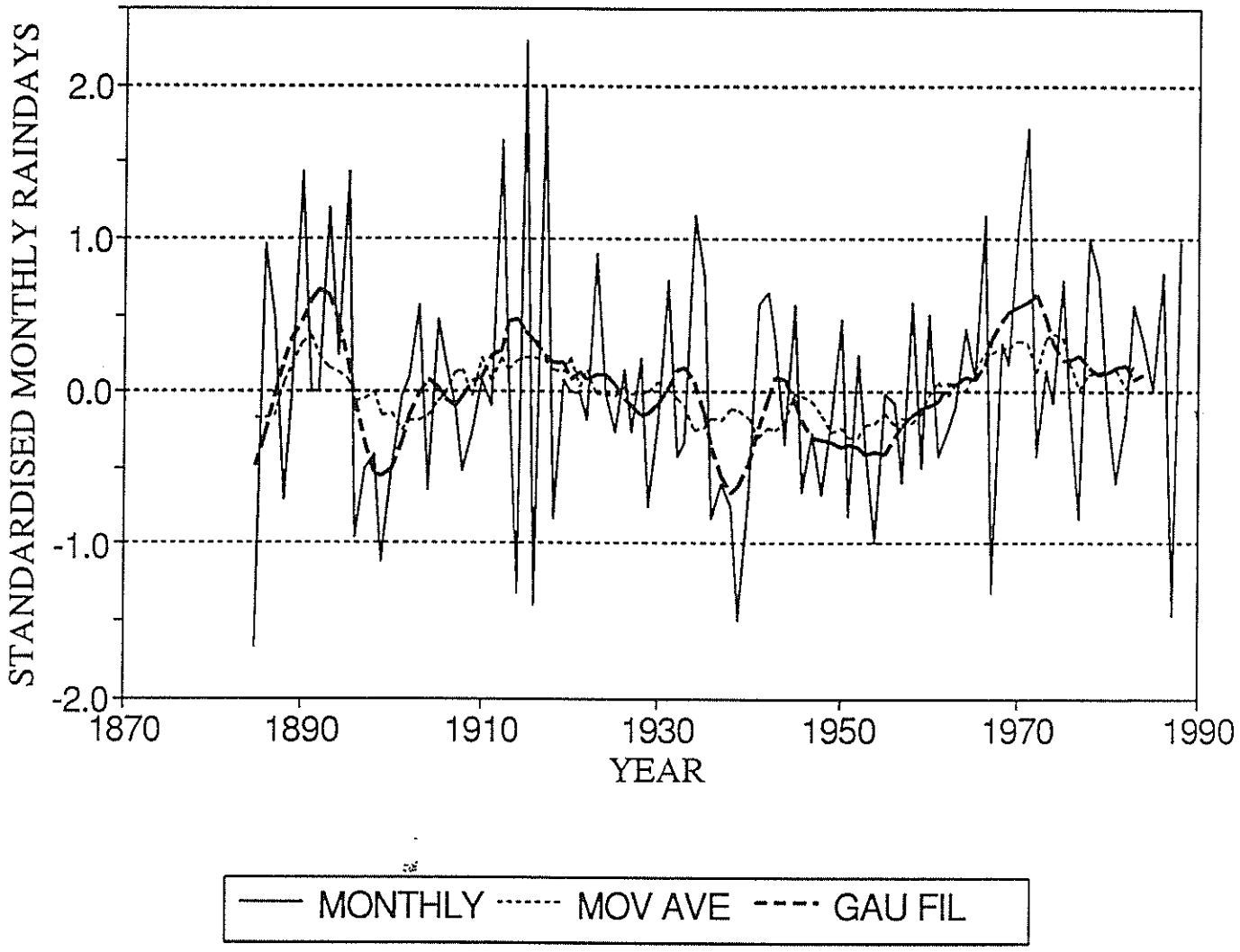


Fig C77. Plot of September raindays time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

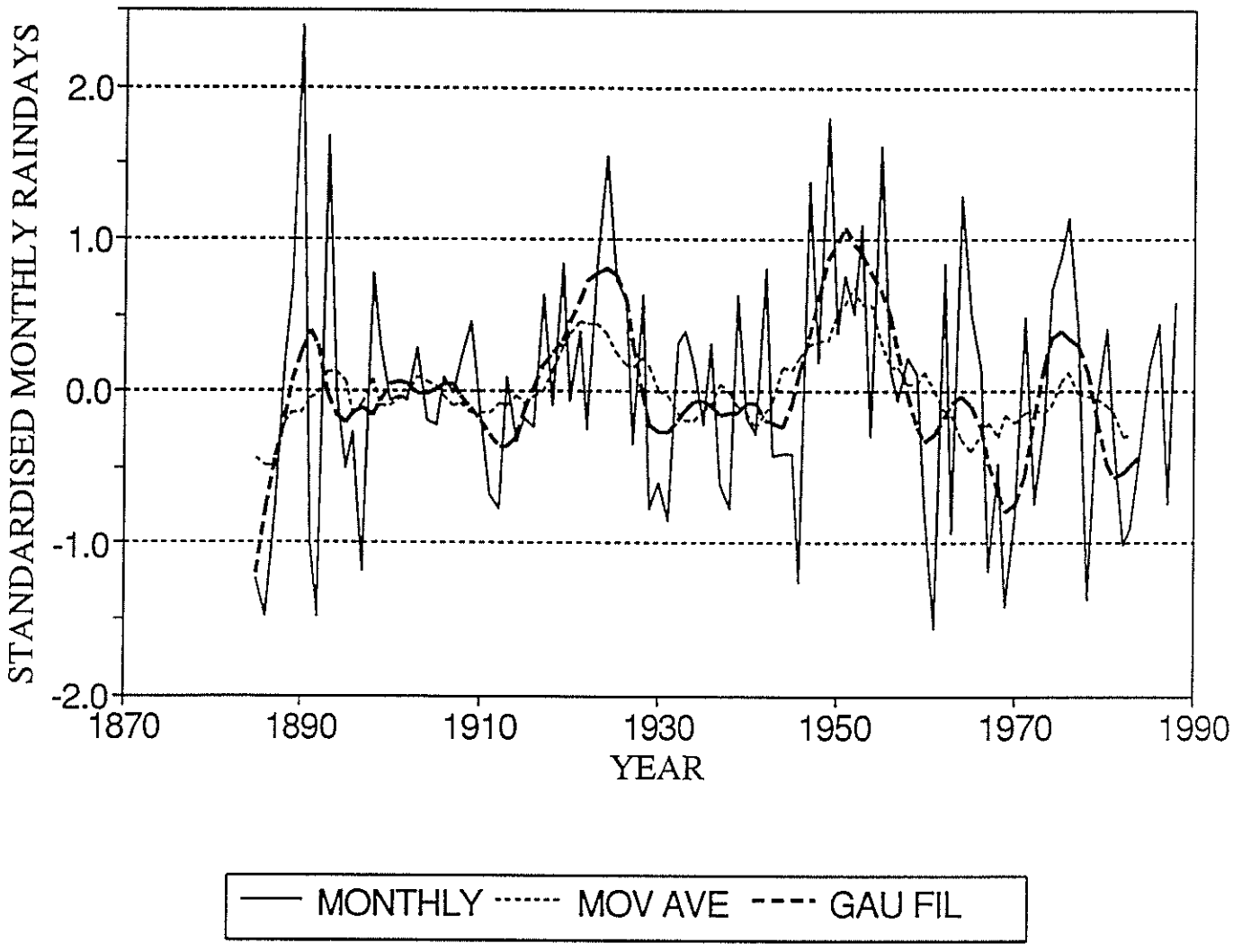


Fig C78. Plot of October raindays time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

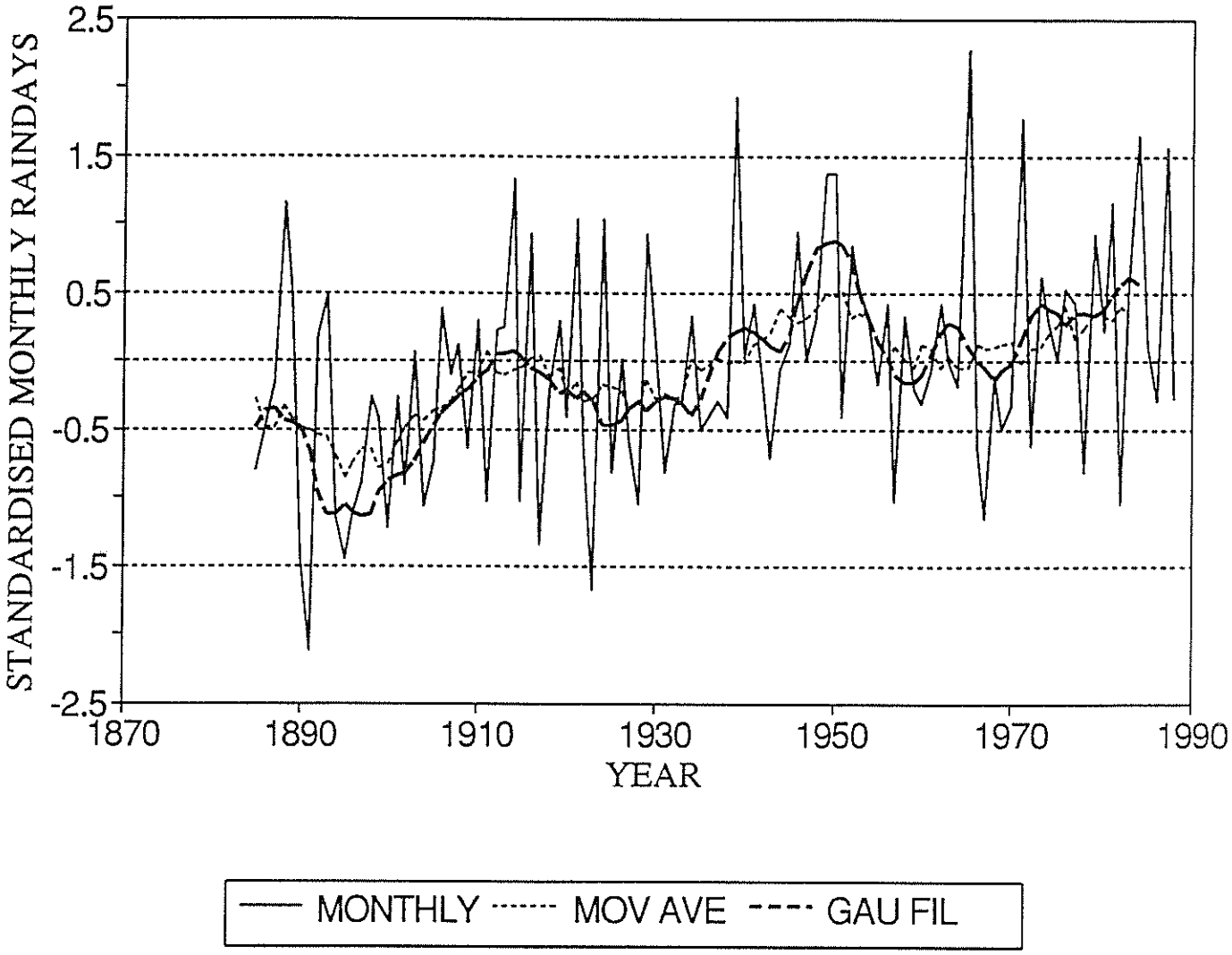


Fig C79. Plot of November raindays time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

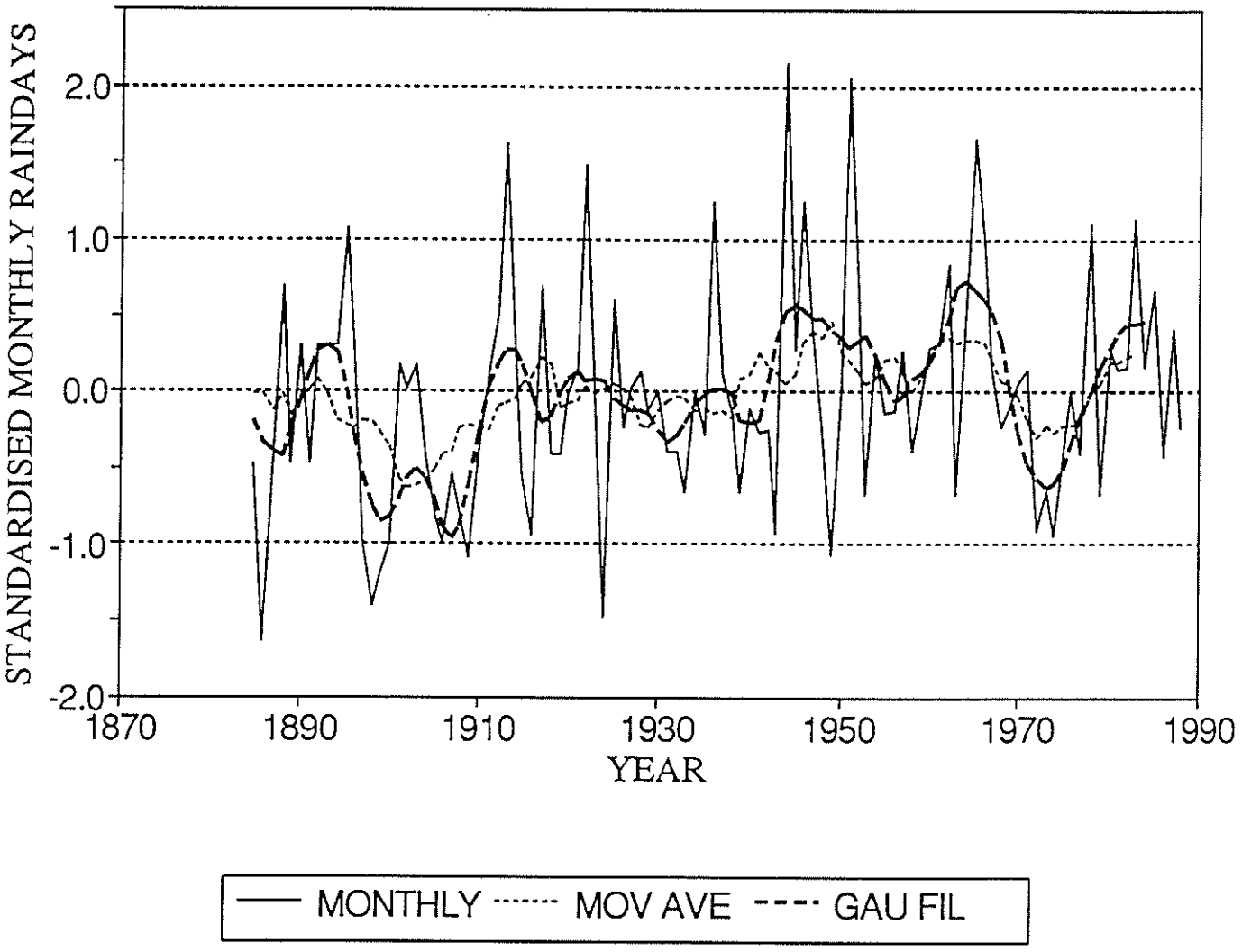


Fig C80. Plot of December raindays time series with 11 year moving average and 11 point Gaussian filter for winter (moderate to heavy) region.

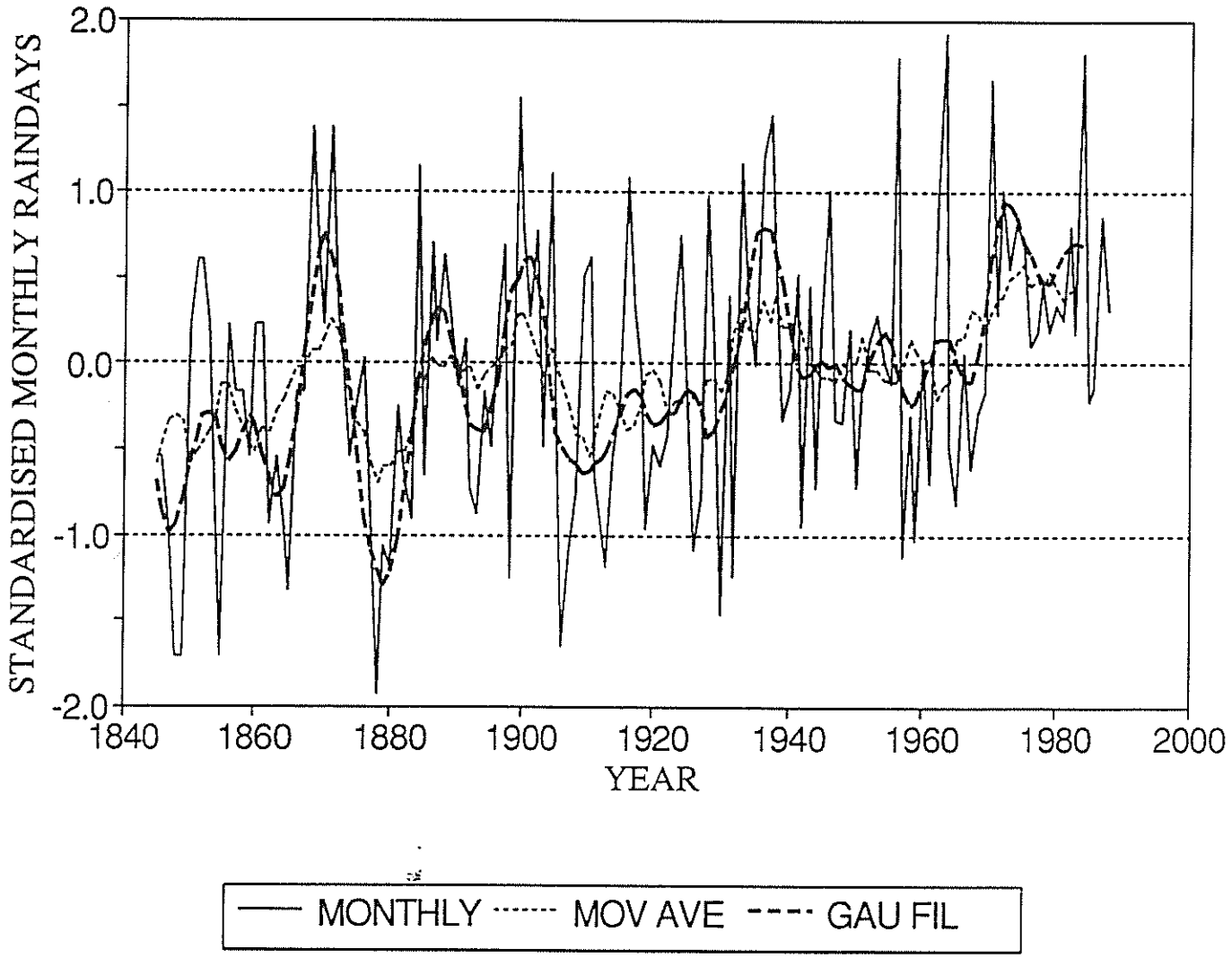


Fig C81. Plot of January raindays time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

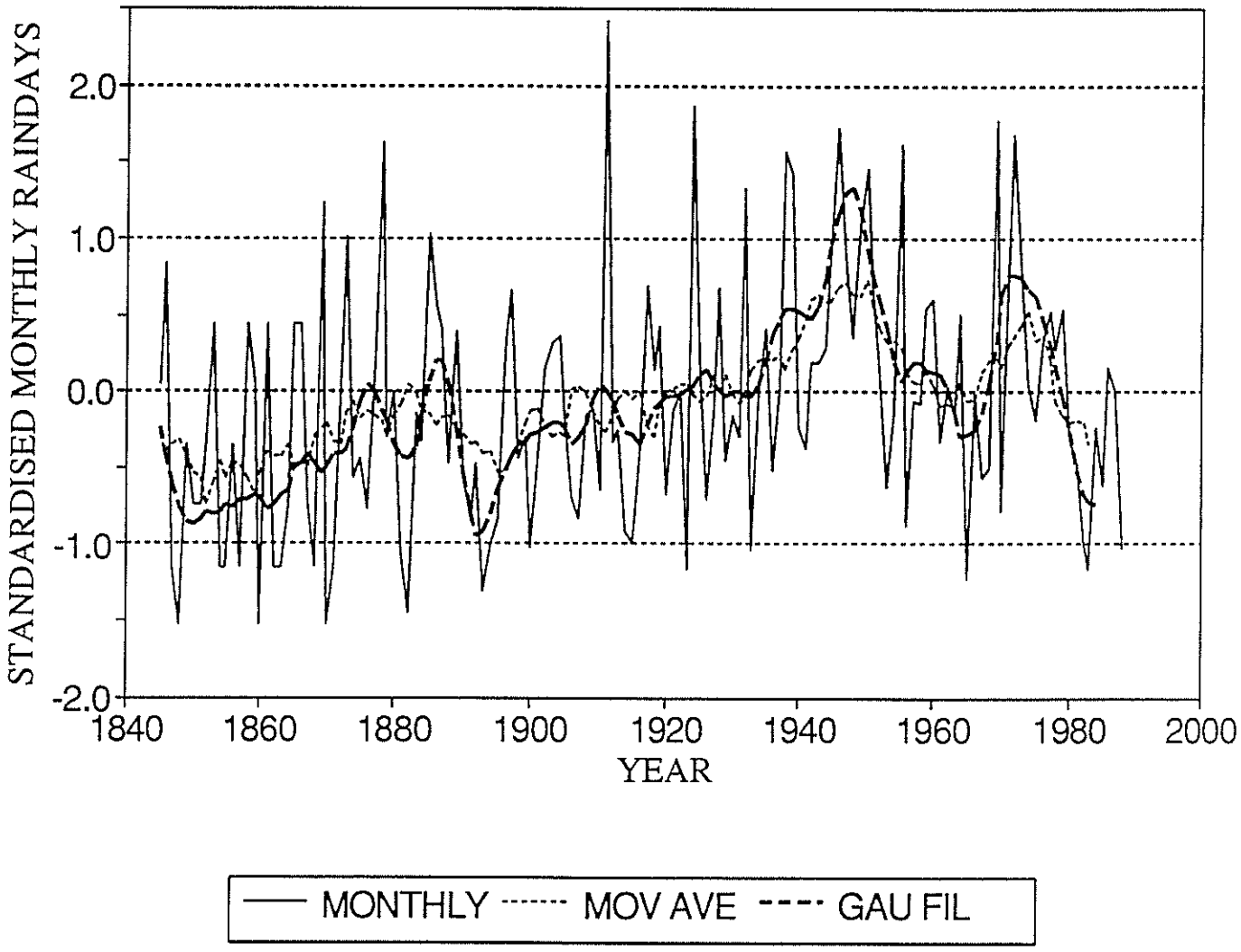


Fig C82. Plot of February raindays time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

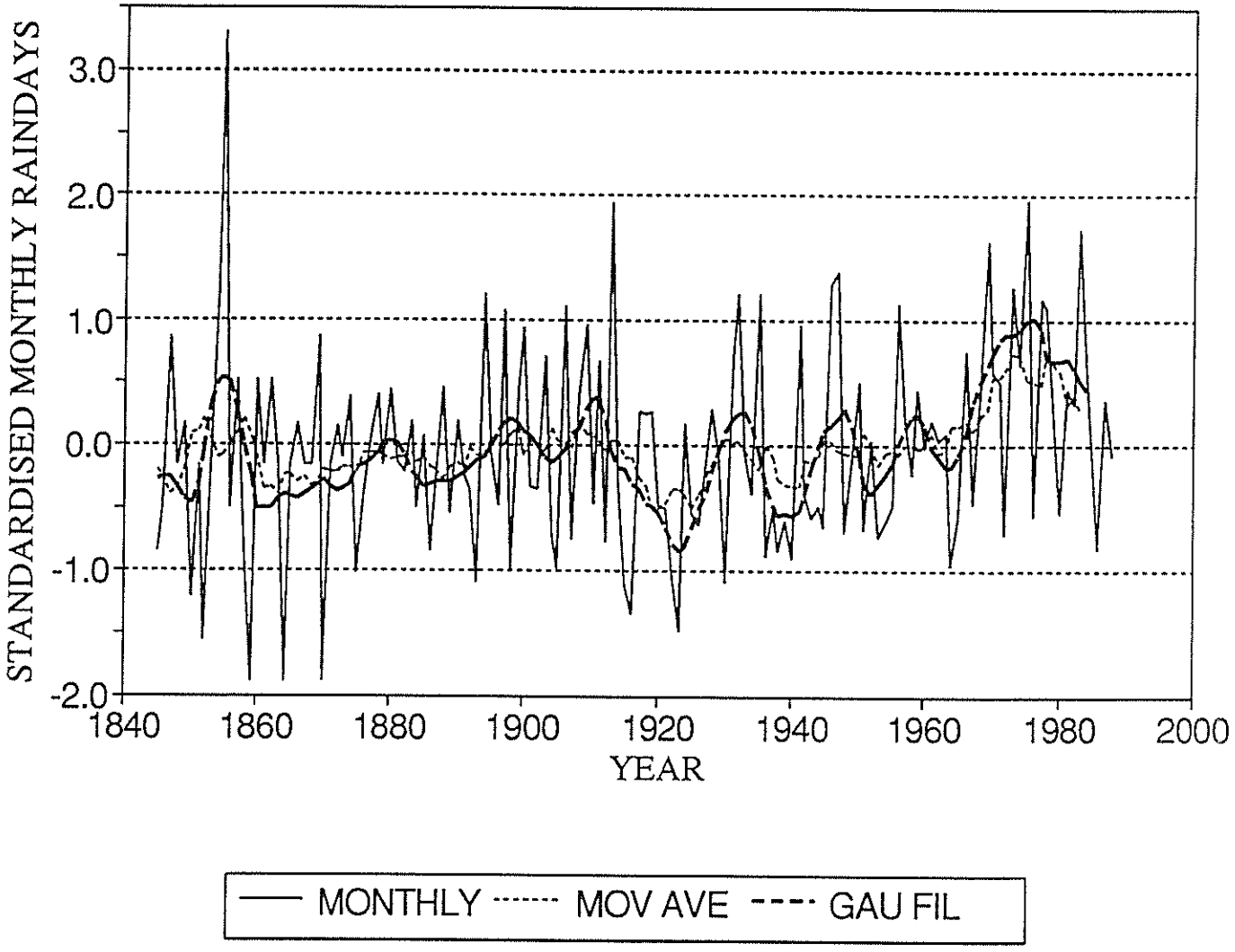


Fig C83. Plot of March raindays time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

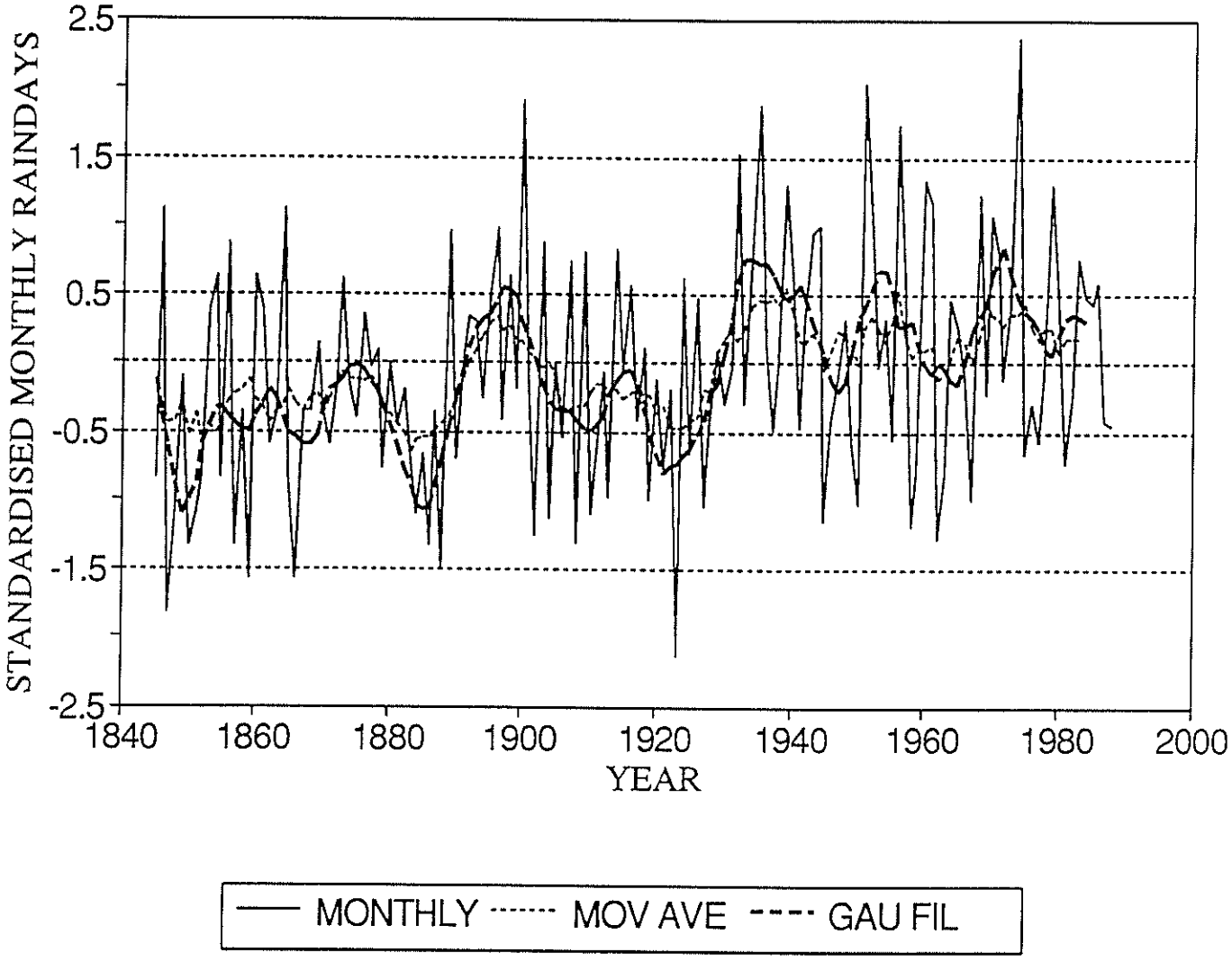


Fig C84. Plot of April raindays time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

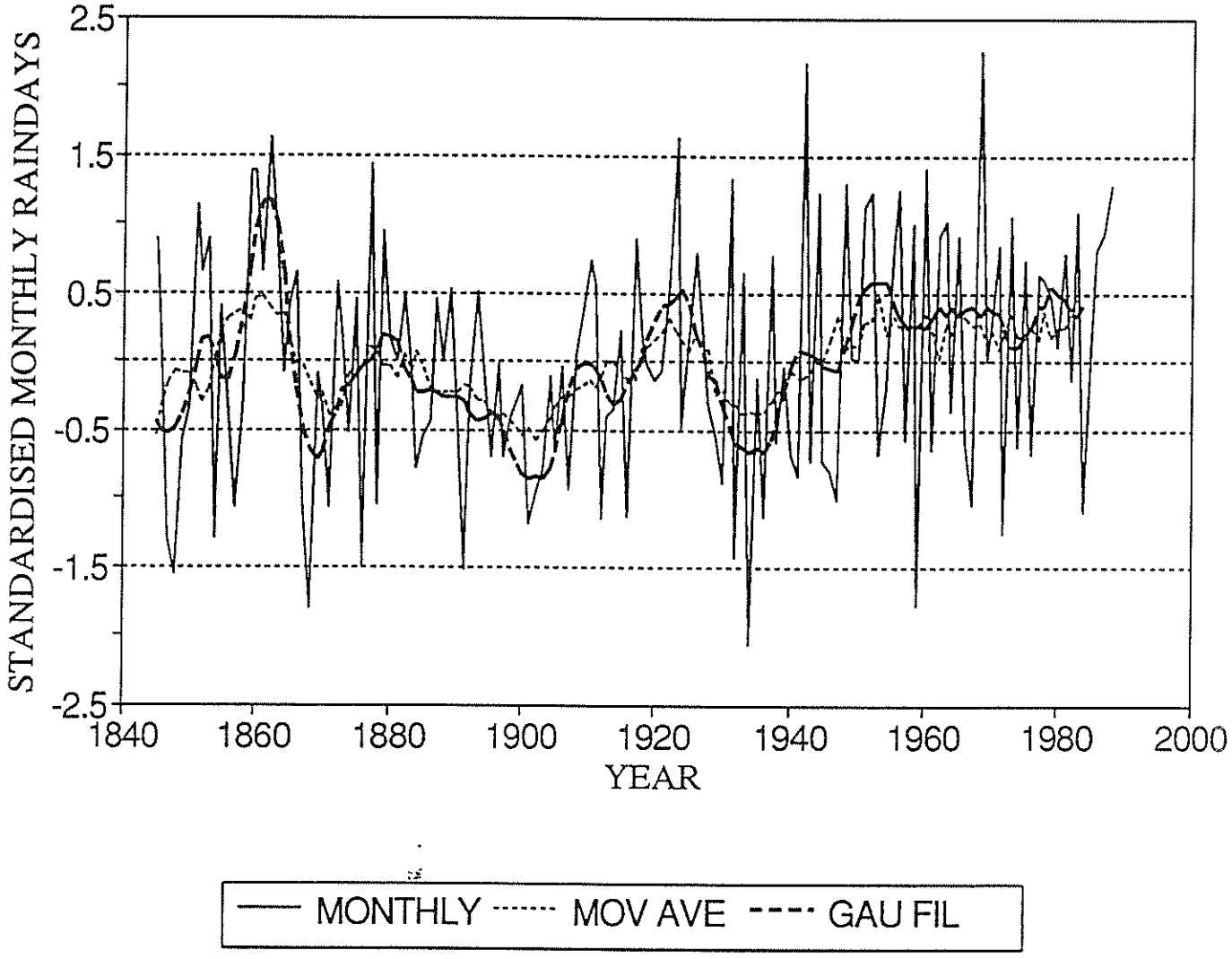


Fig C85. Plot of May raindays time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

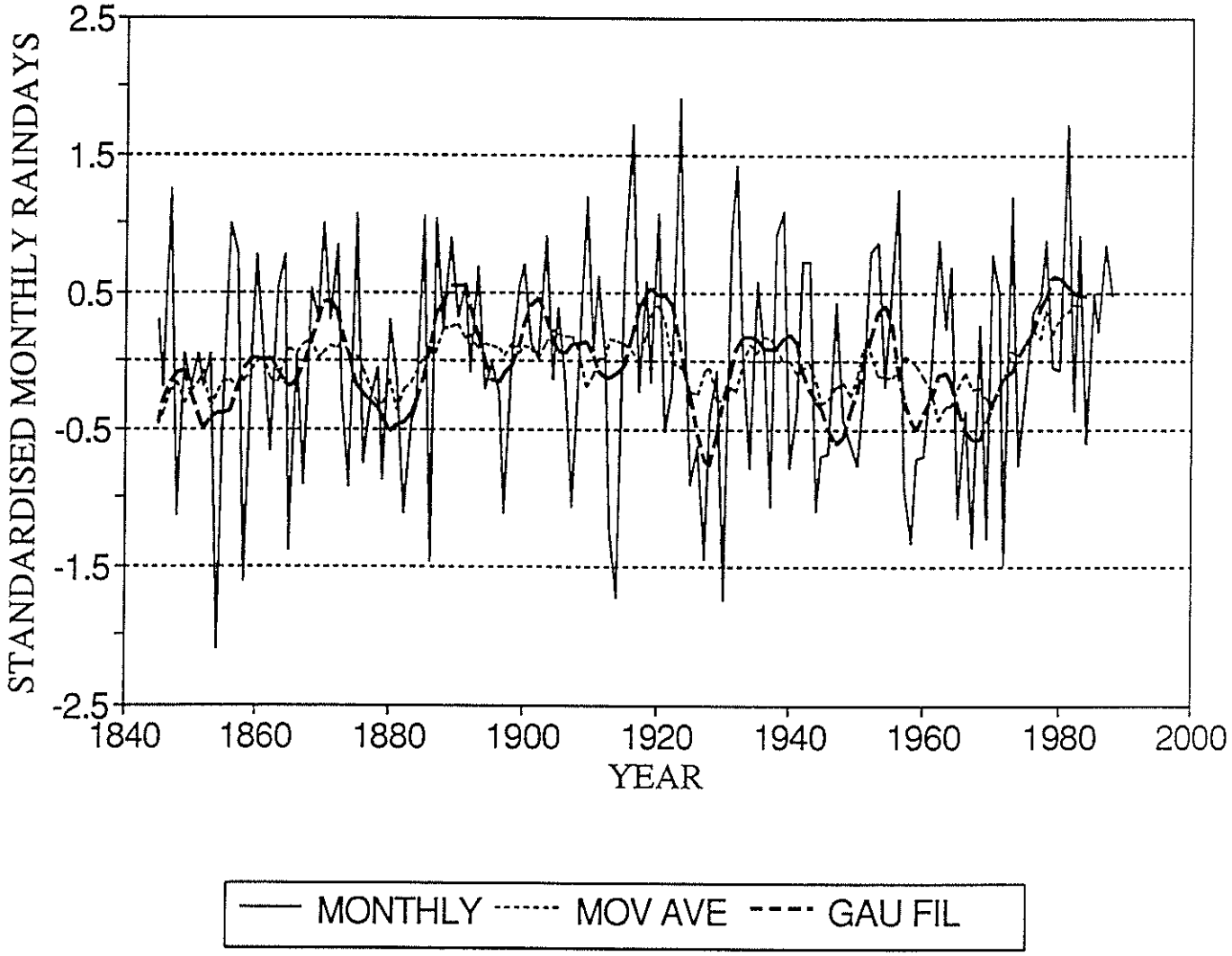


Fig C86. Plot of June raindays time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

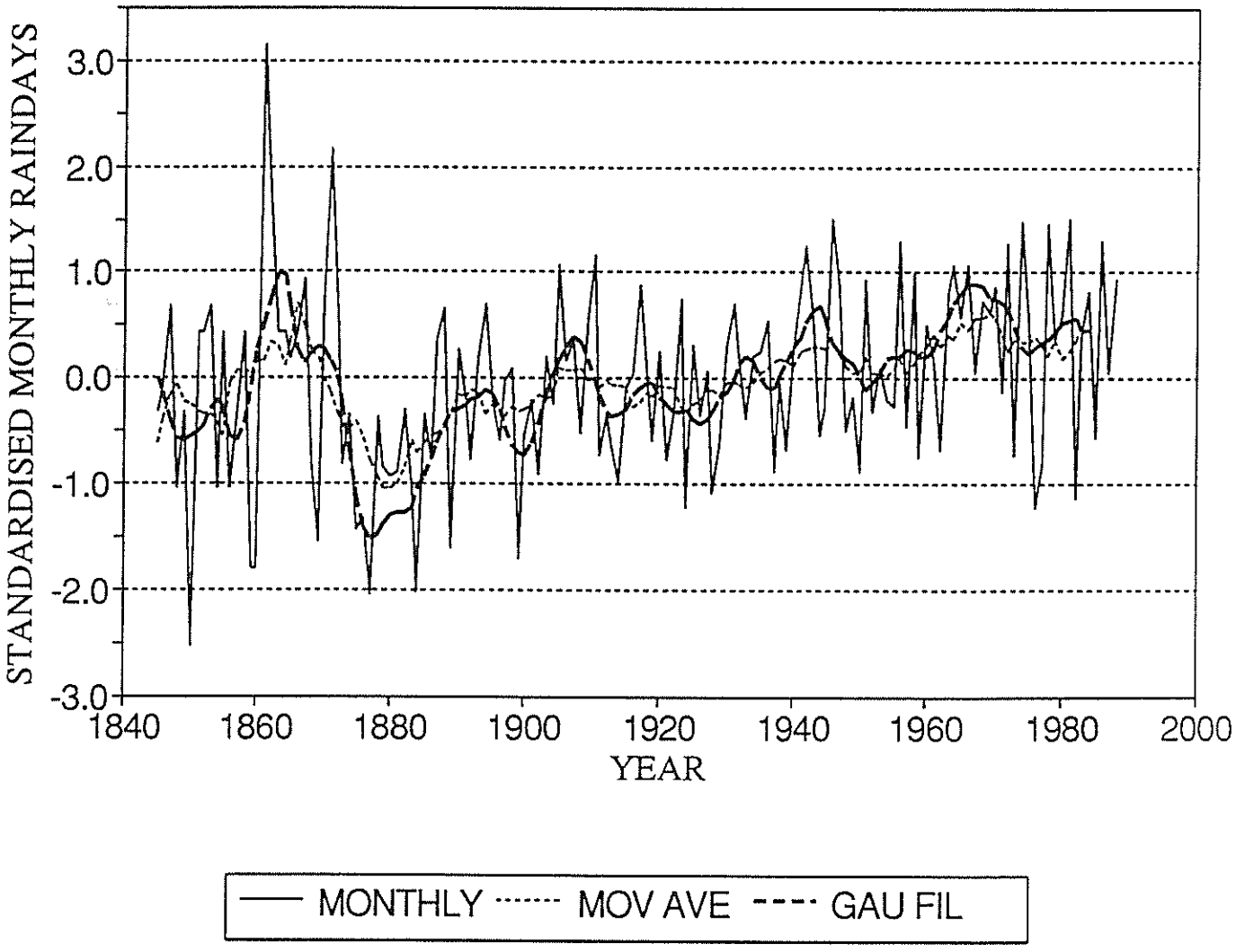


Fig C87. Plot of July raindays time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

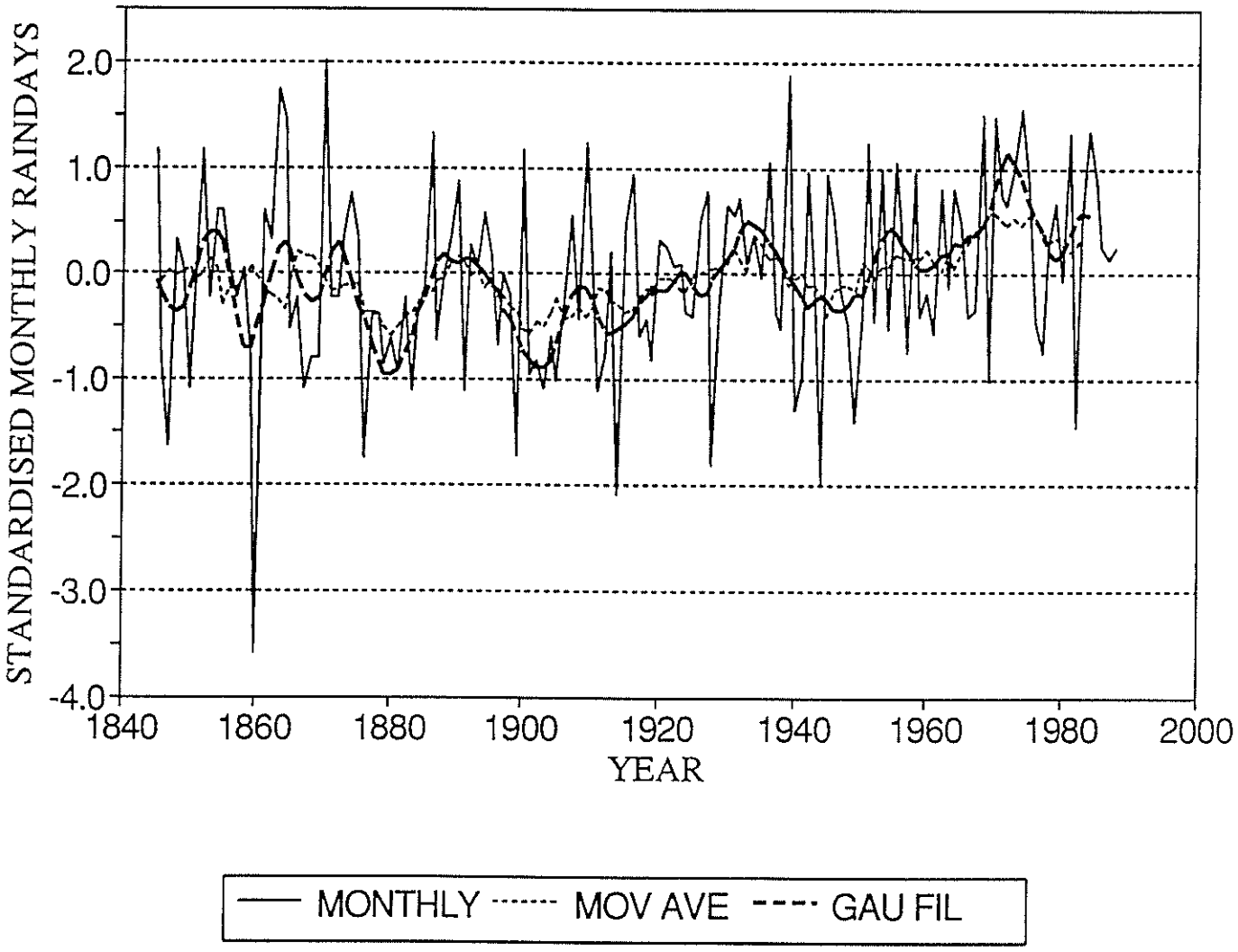


Fig C88. Plot of August raindays time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

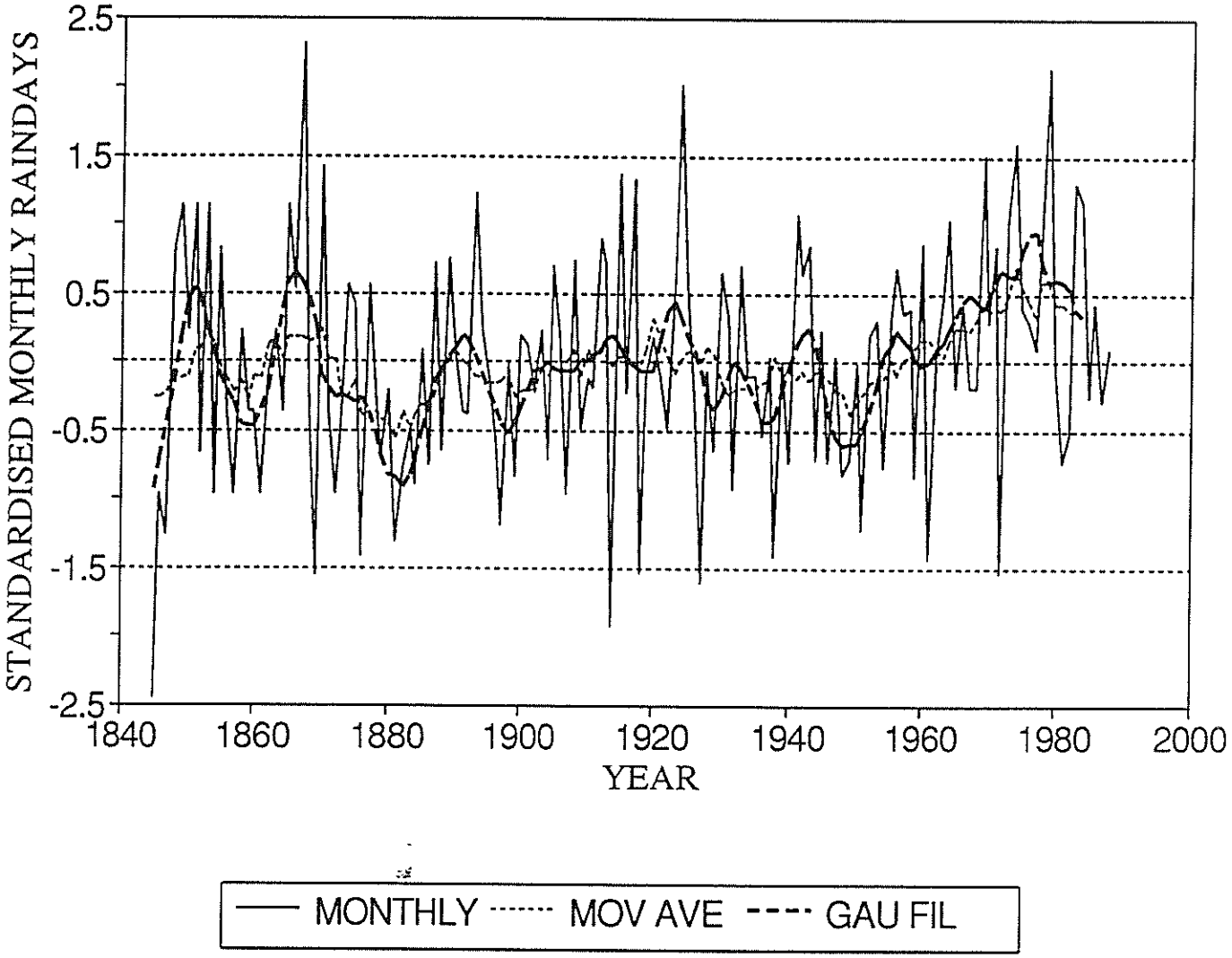


Fig C89. Plot of September raindays time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

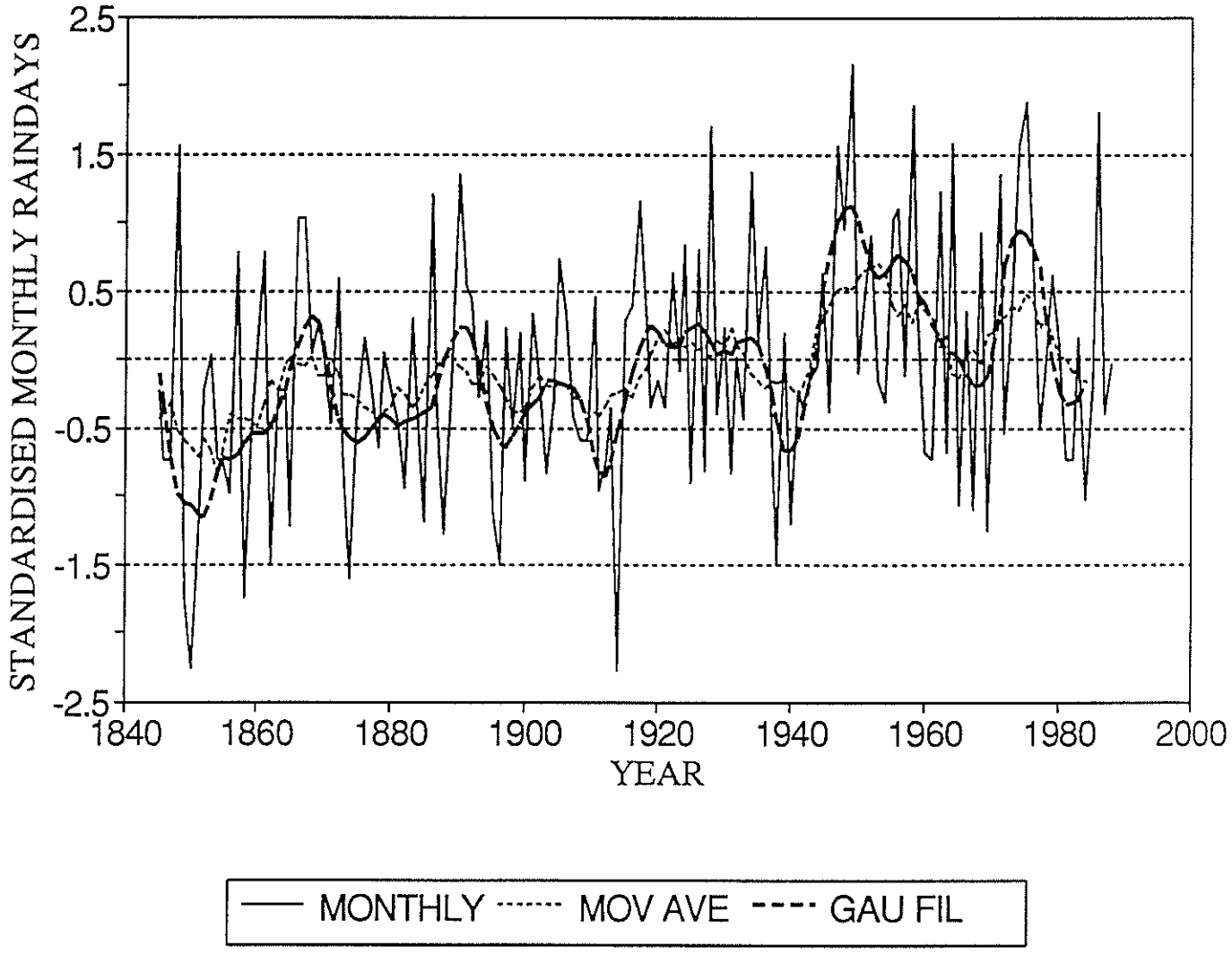


Fig C90. Plot of October raindays time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

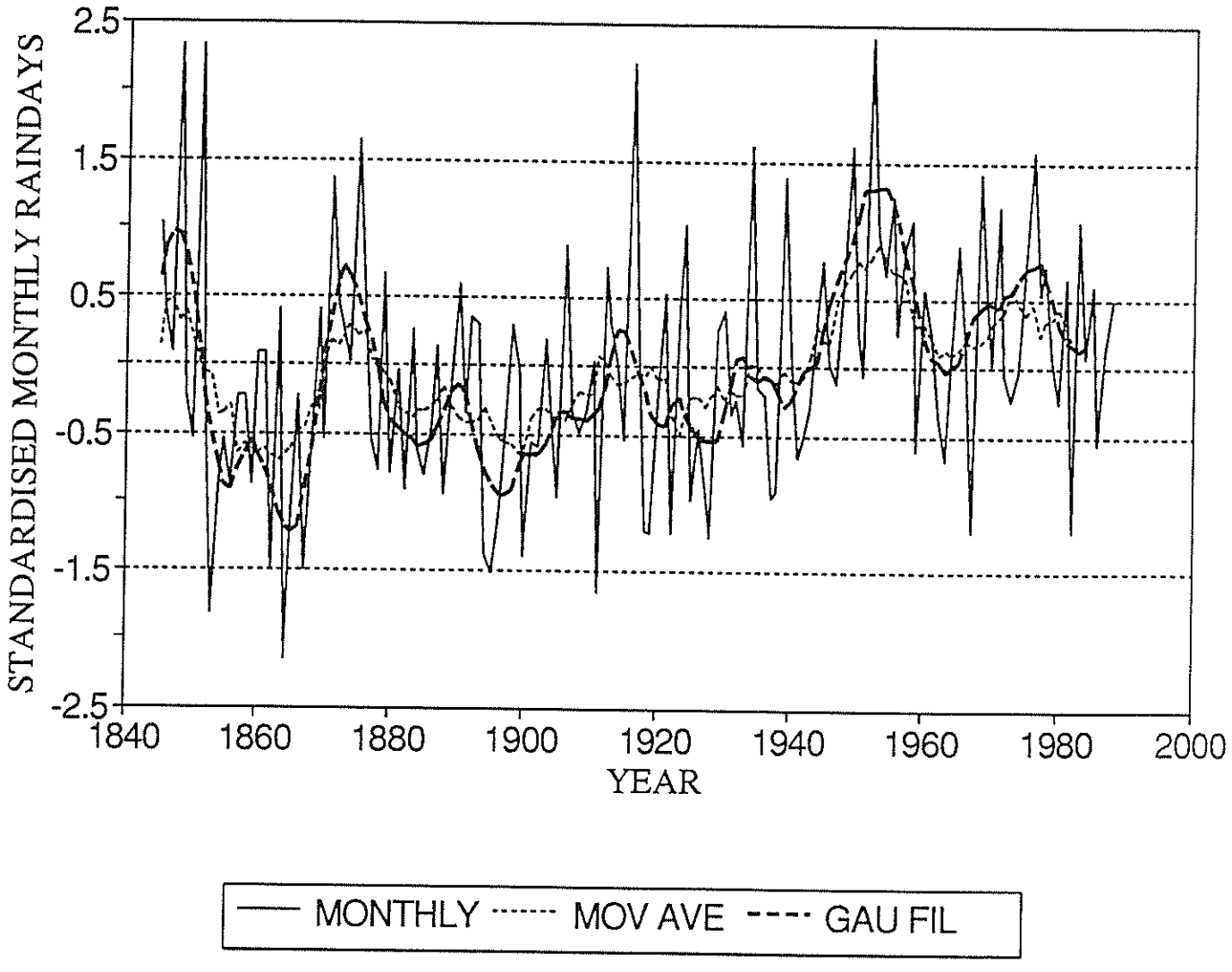


Fig C91. Plot of November raindays time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

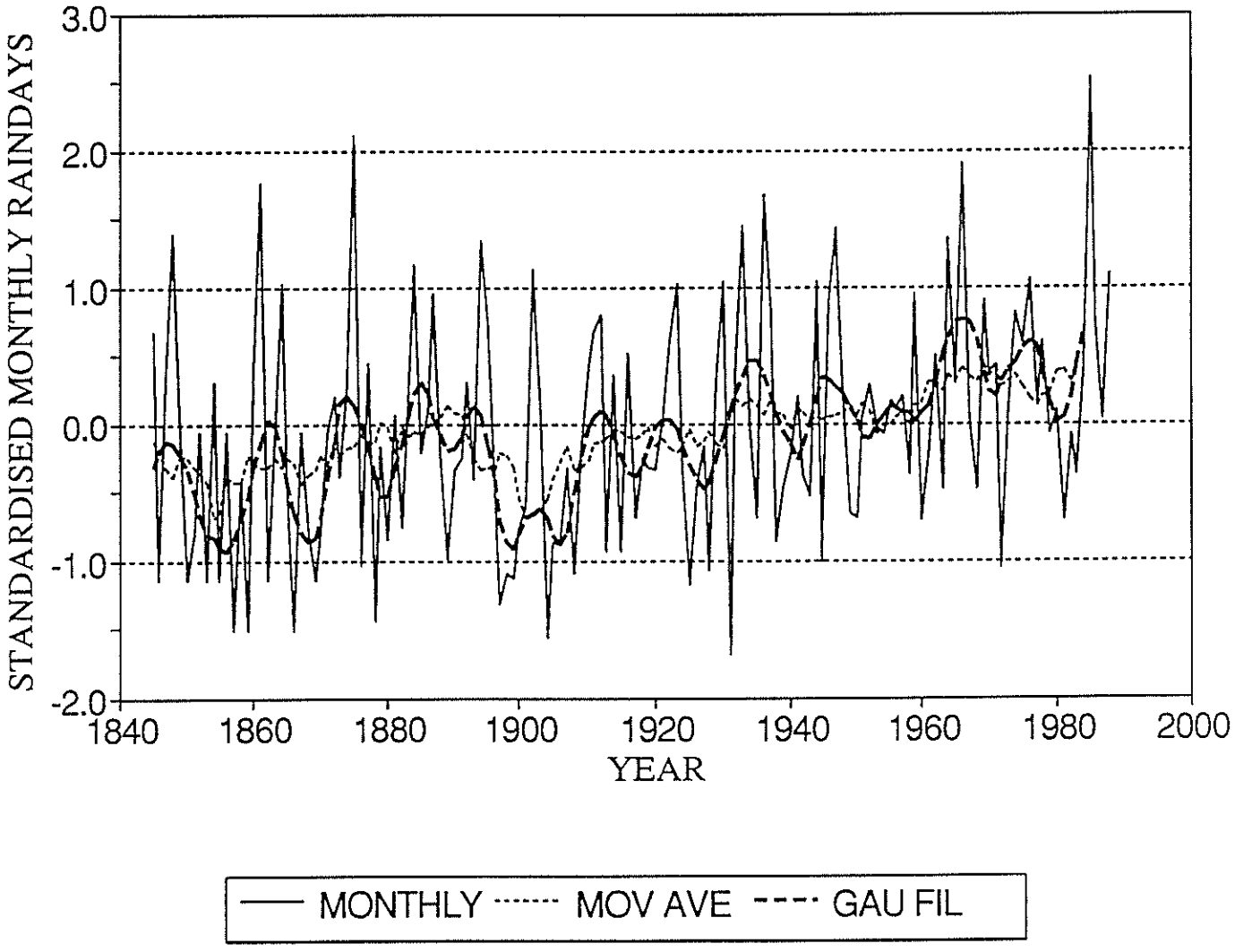


Fig C92. Plot of December raindays time series with 11 year moving average and 11 point Gaussian filter for winter (mainly moderate) region.

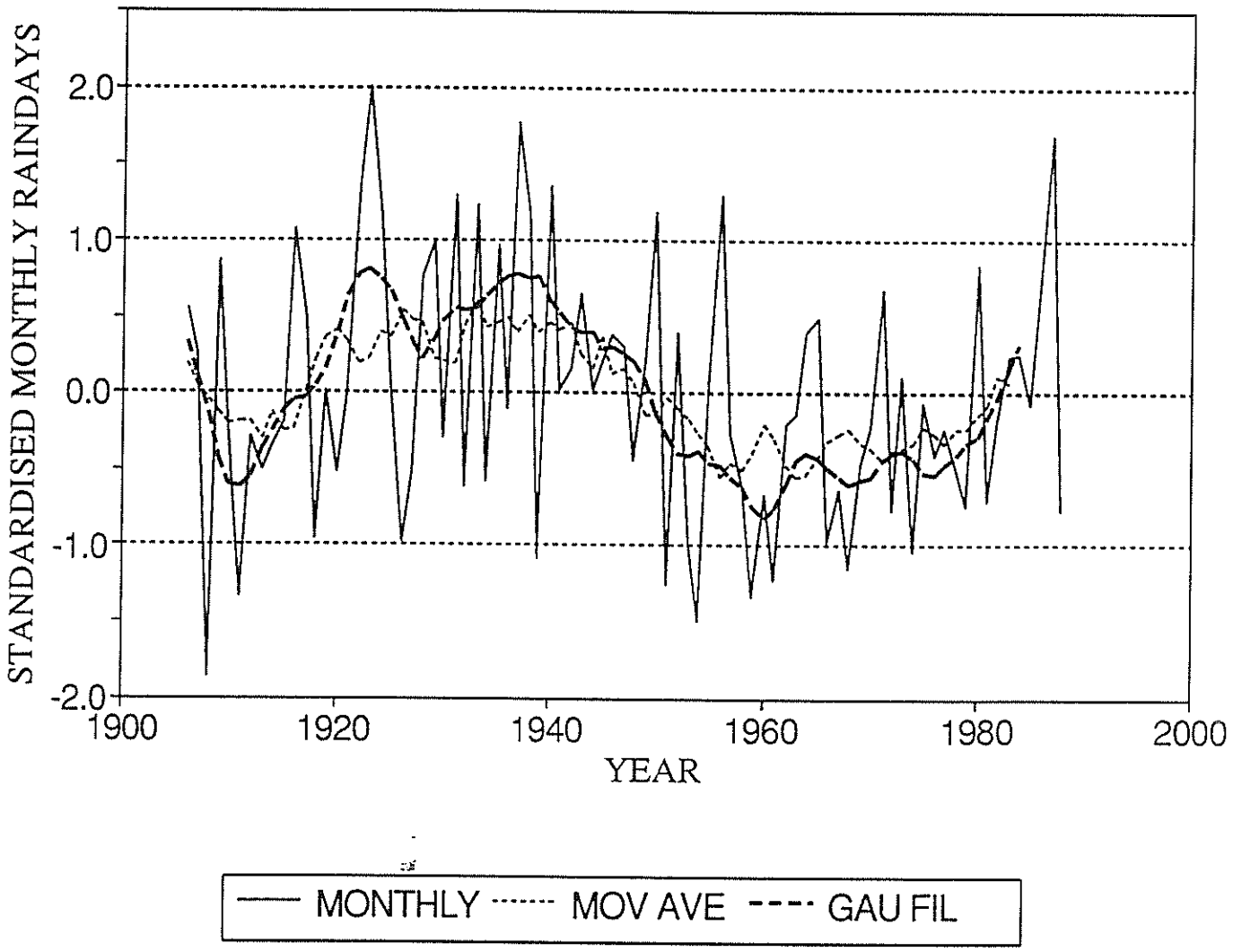


Fig C93. Plot of January raindays time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

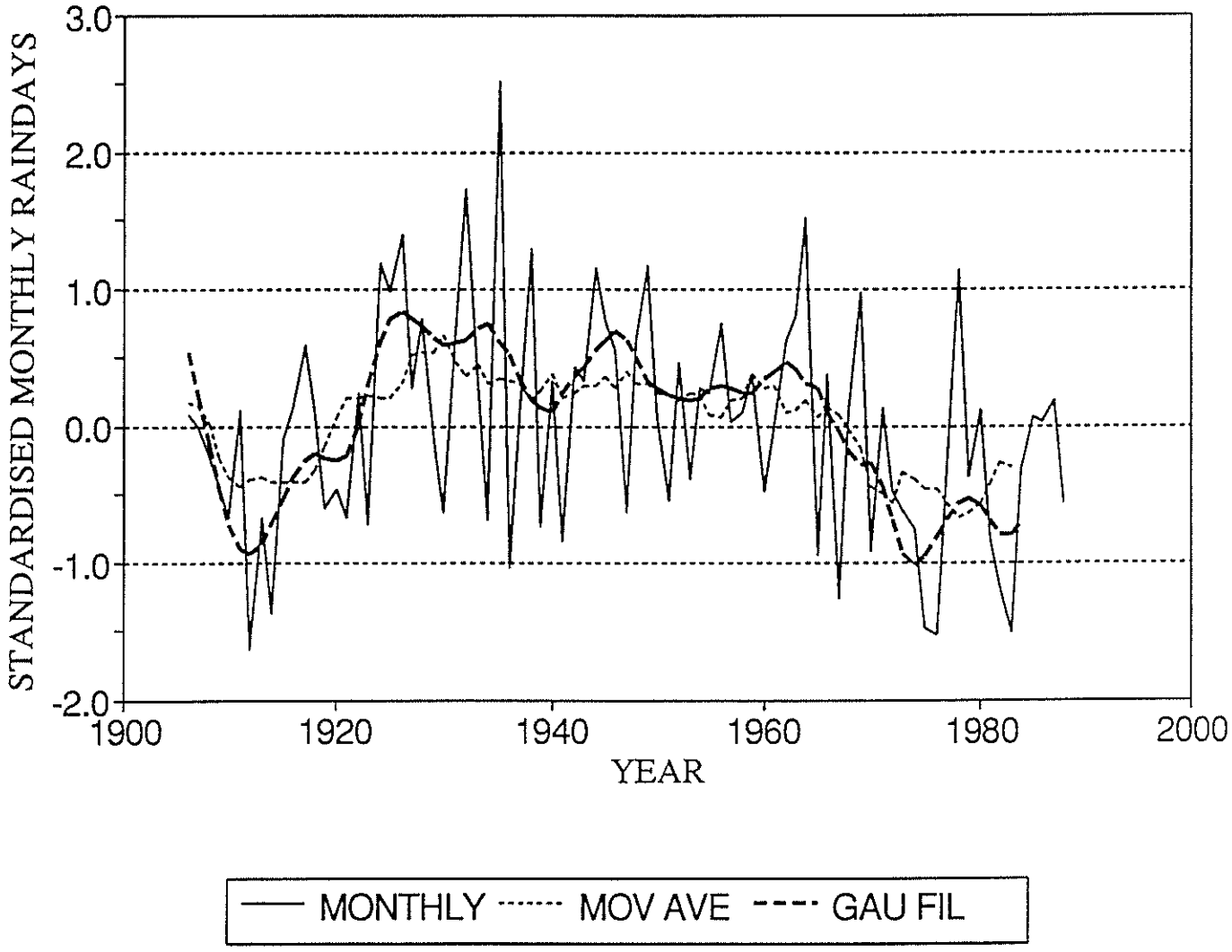


Fig C94. Plot of February raindays time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

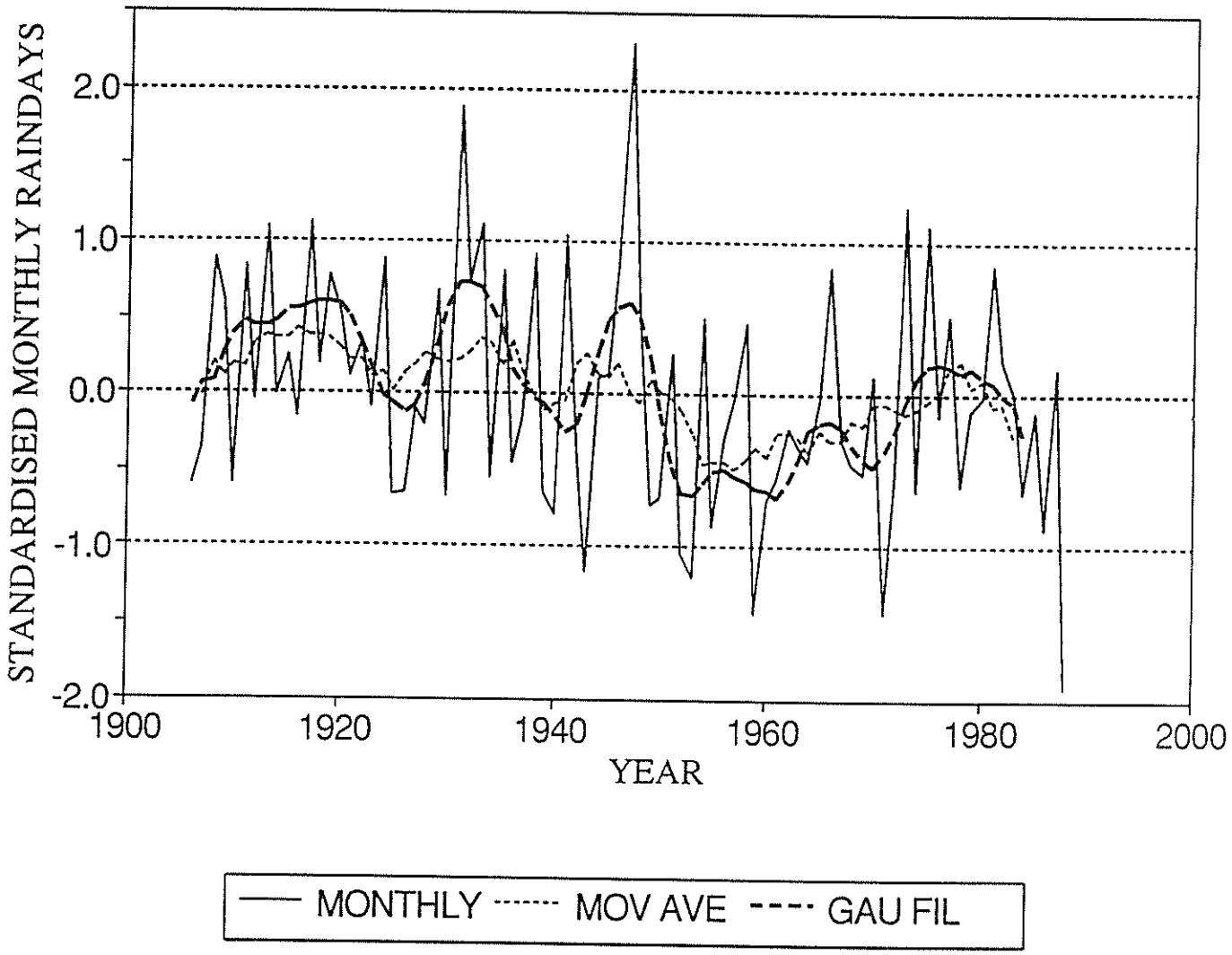


Fig C95. Plot of March raindays time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

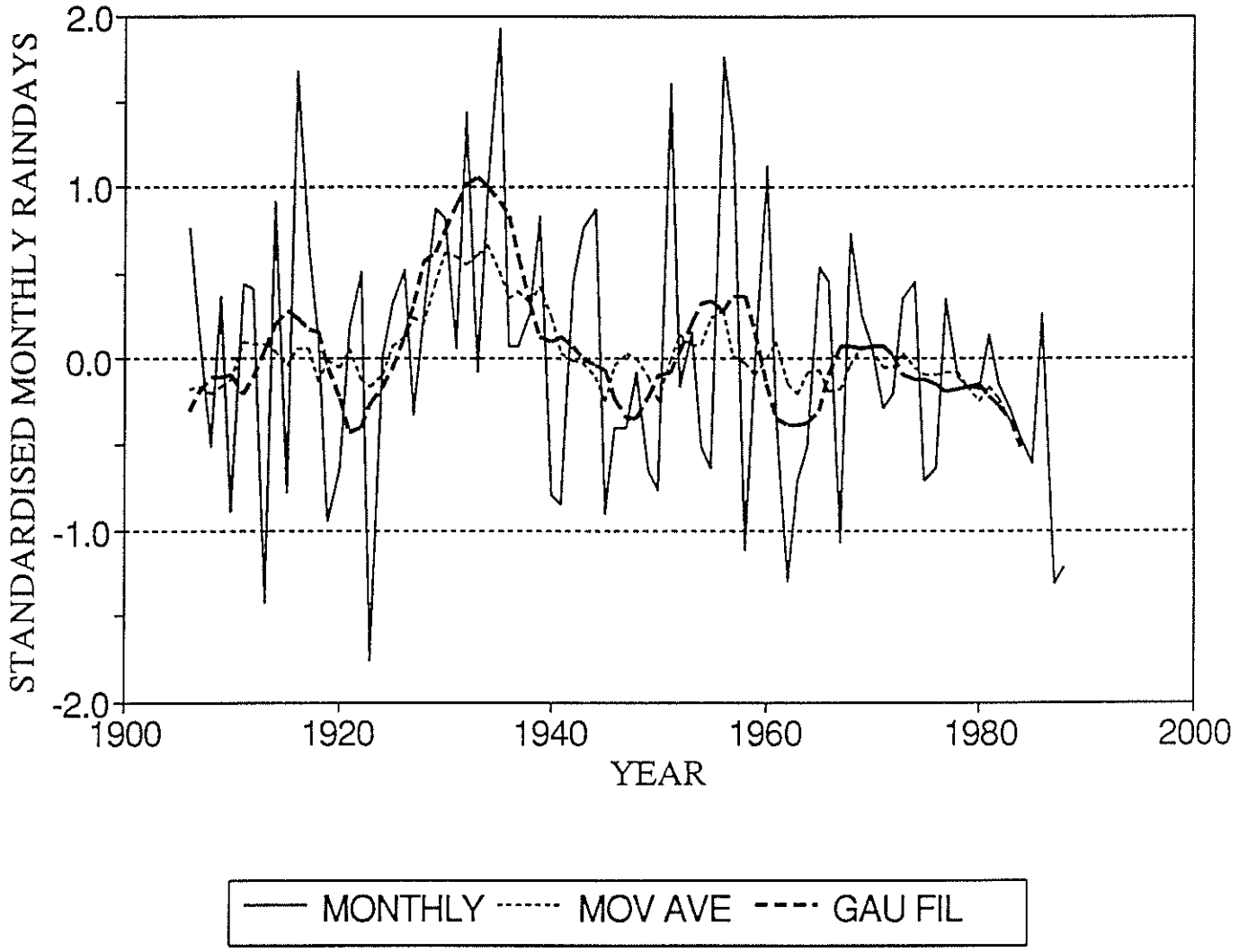


Fig C96. Plot of April raindays time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

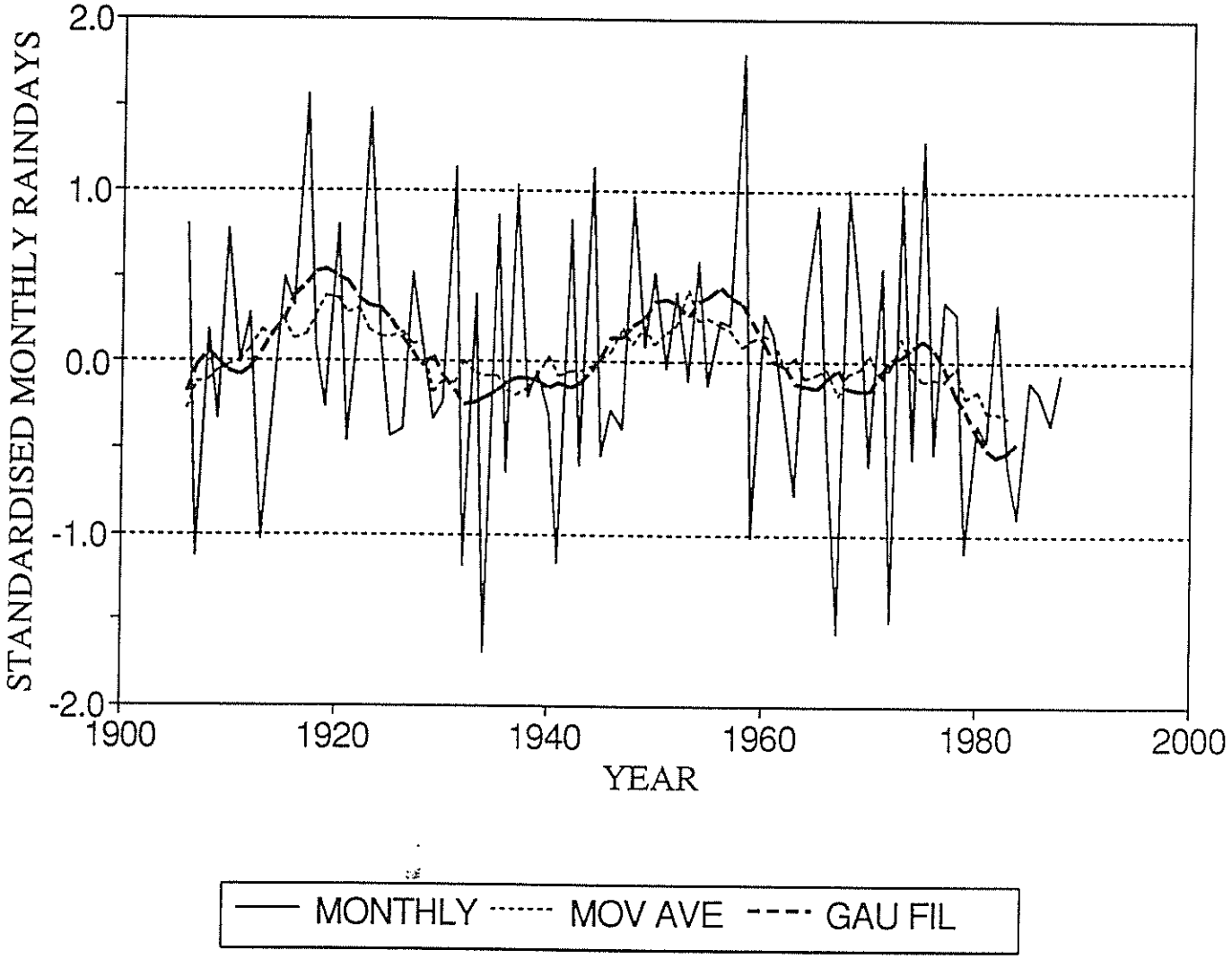


Fig C97. Plot of May raindays time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

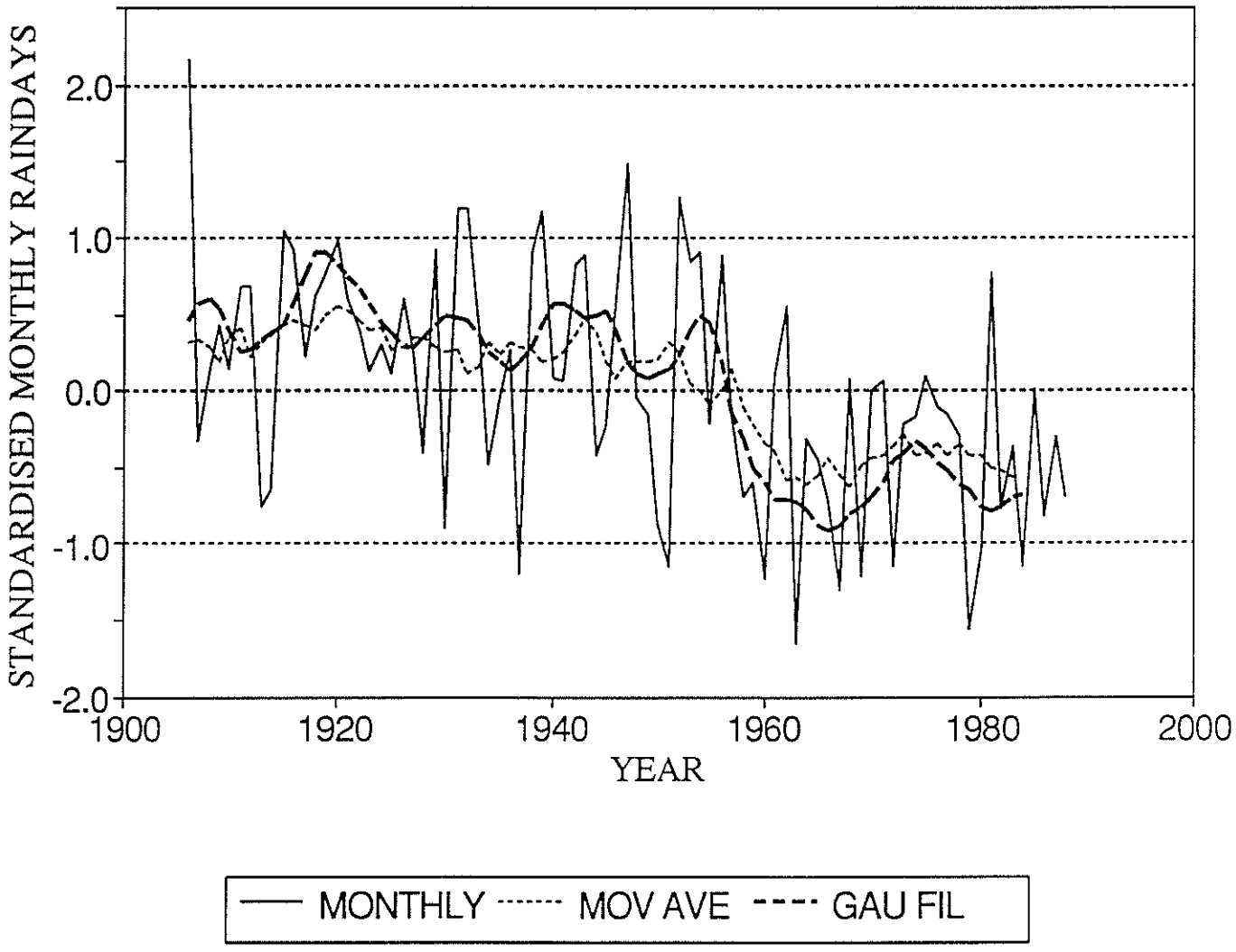


Fig C98. Plot of June raindays time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

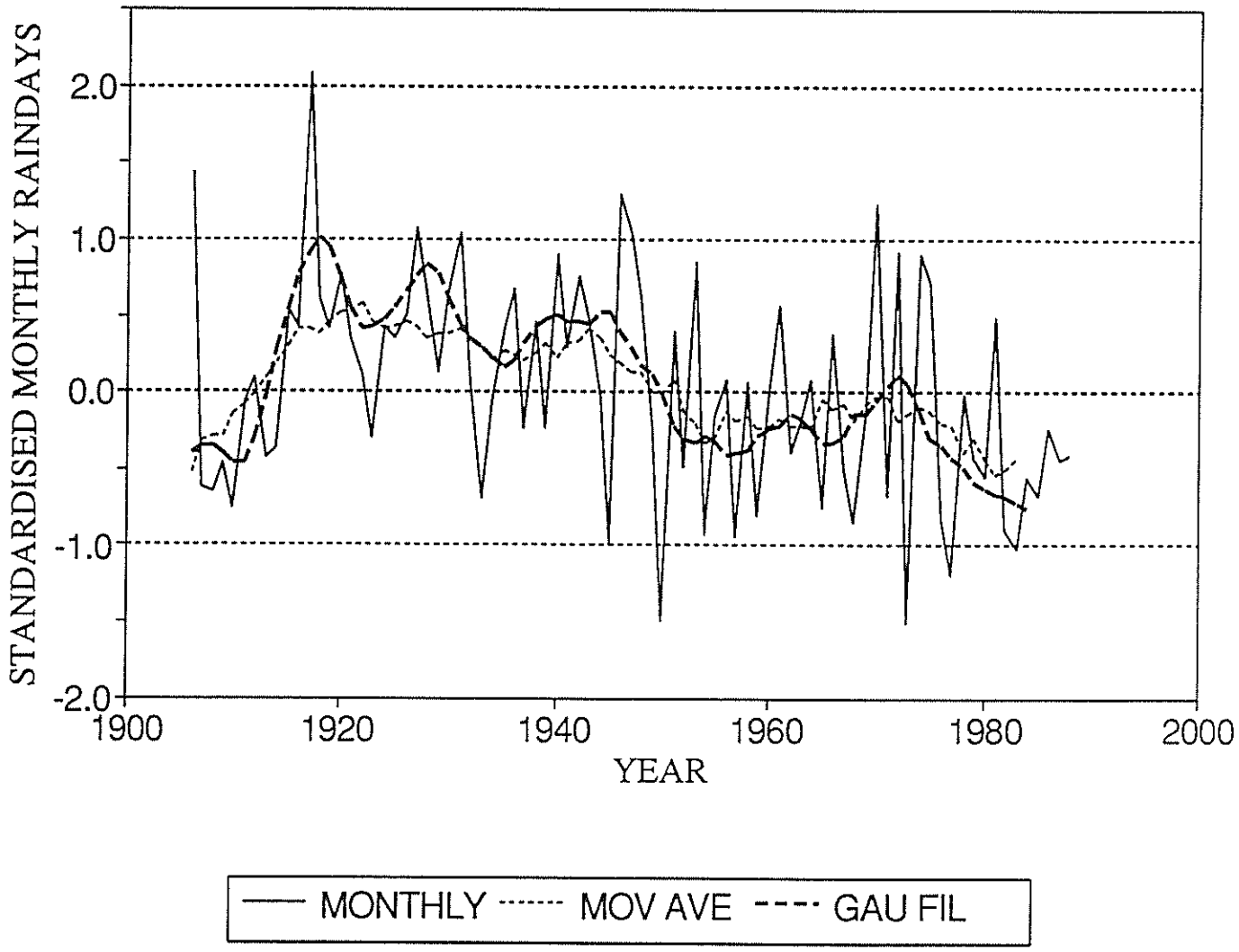


Fig C99. Plot of July raindays time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

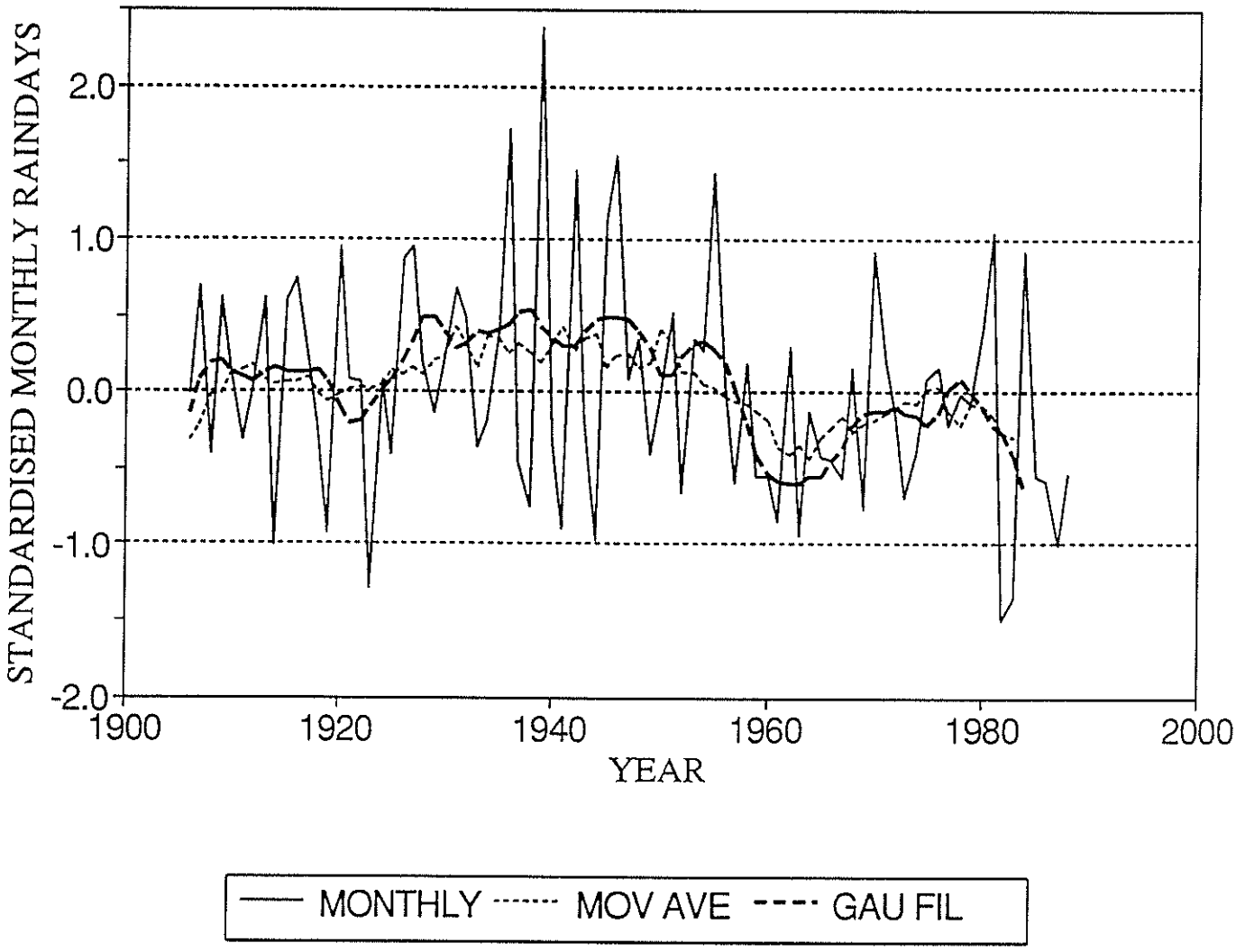


Fig C100. Plot of August raindays time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

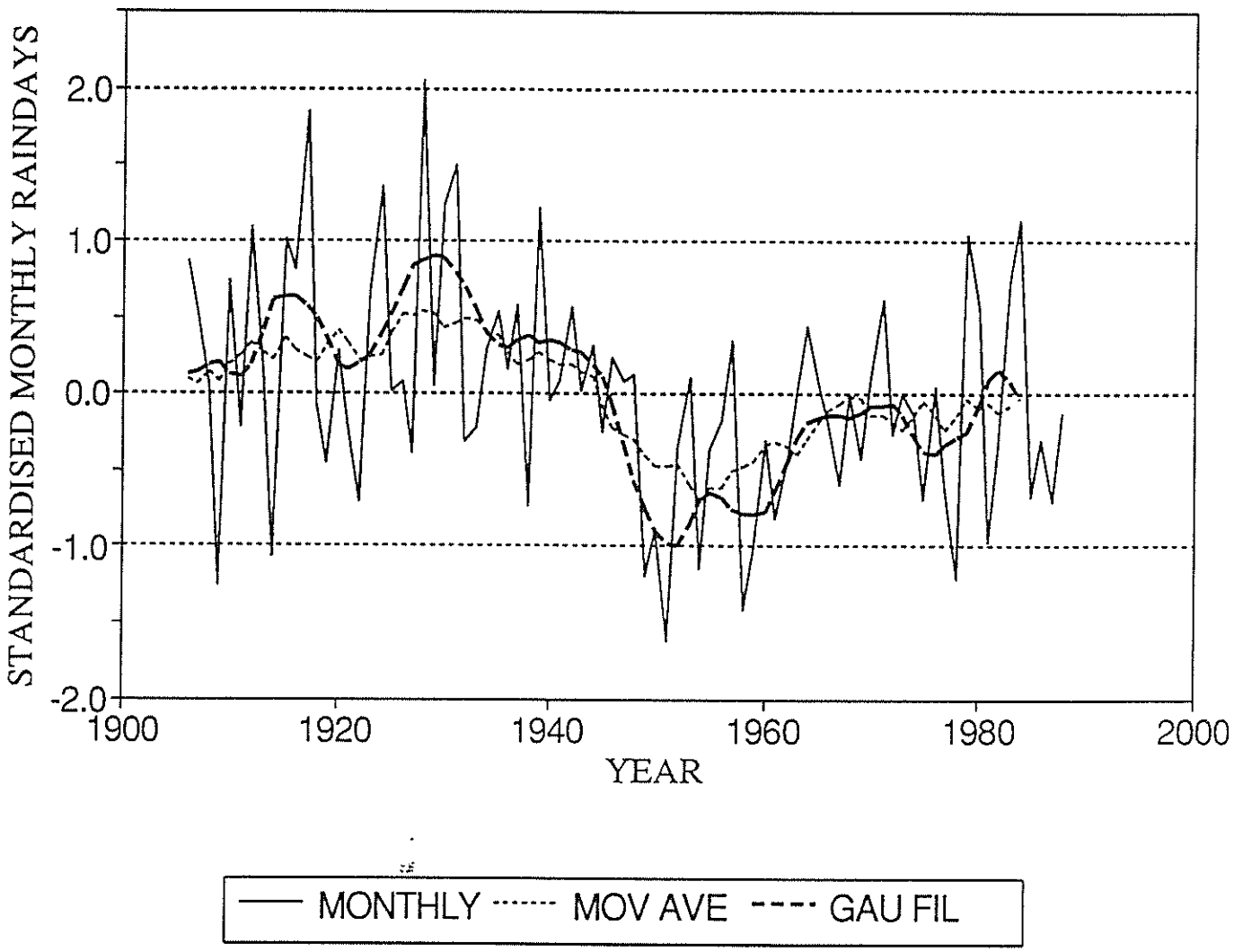


Fig C101. Plot of September raindays time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

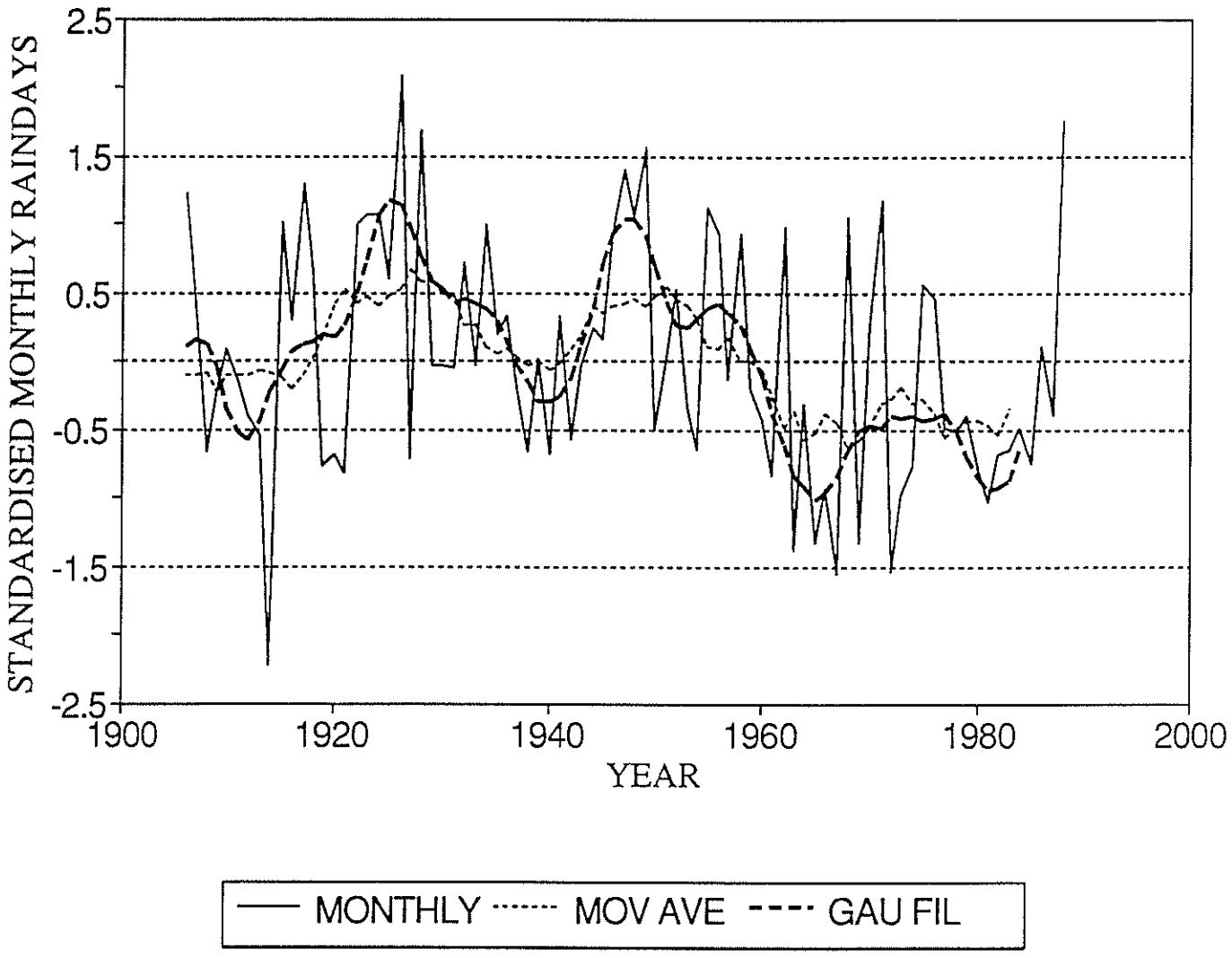


Fig C102. Plot of October raindays time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

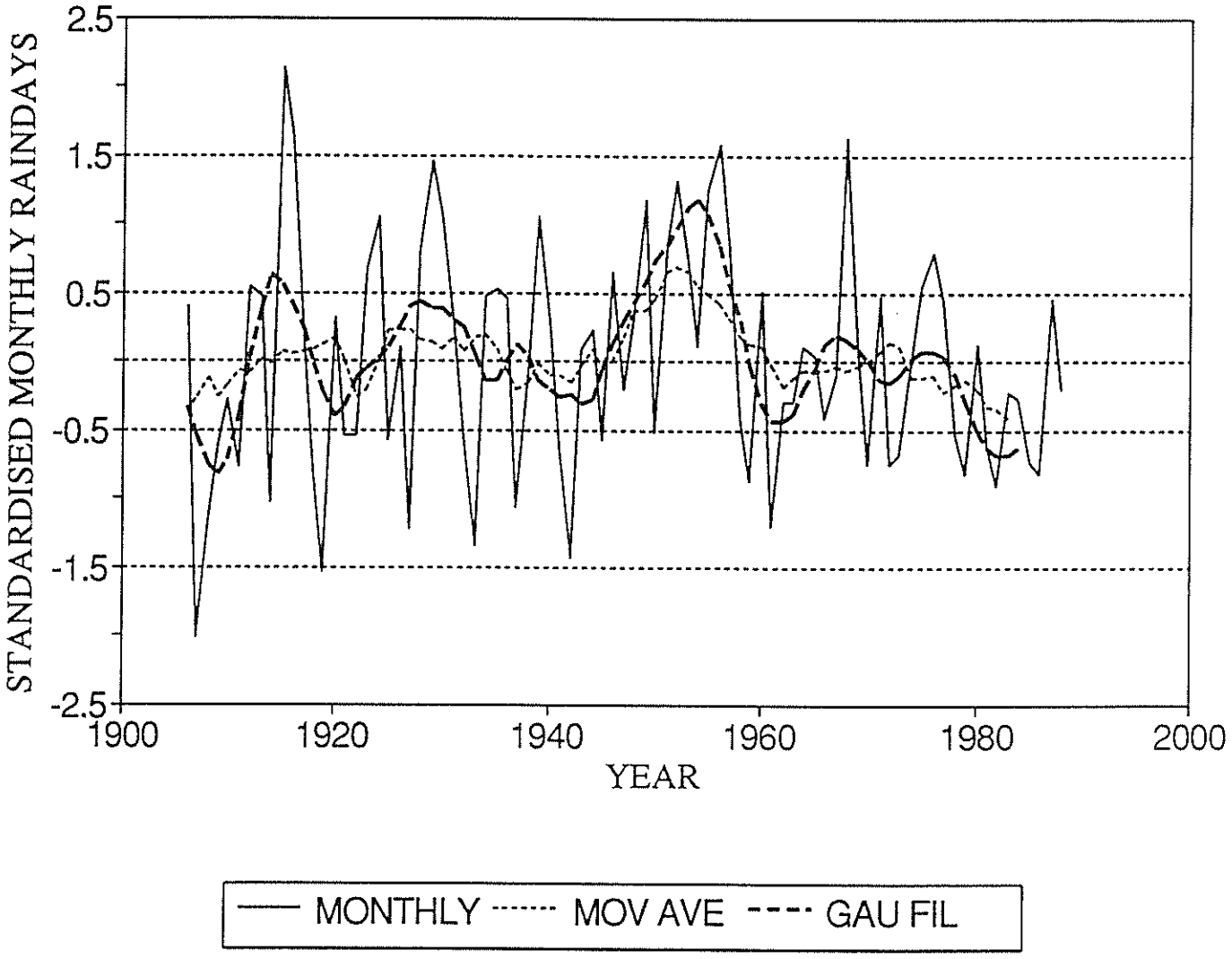


Fig C103. Plot of November raindays time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

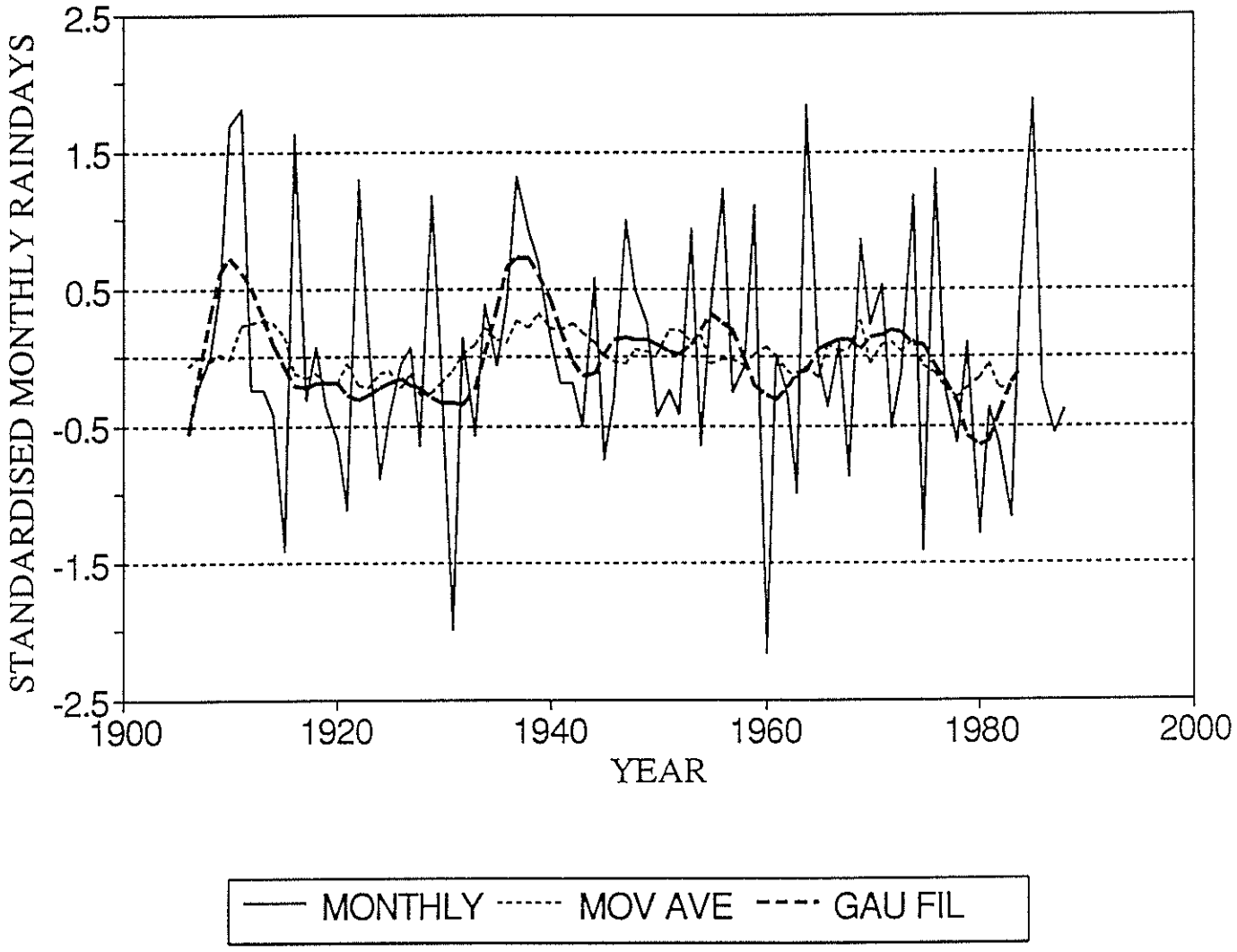


Fig C104. Plot of December raindays time series with 11 year moving average and 11 point Gaussian filter for winter (Tasmania) region.

APPENDIX -D

FIGURES FOR THE ANALYSIS OF ANNUAL MAXIMUM DAILY RAINFALL DATA

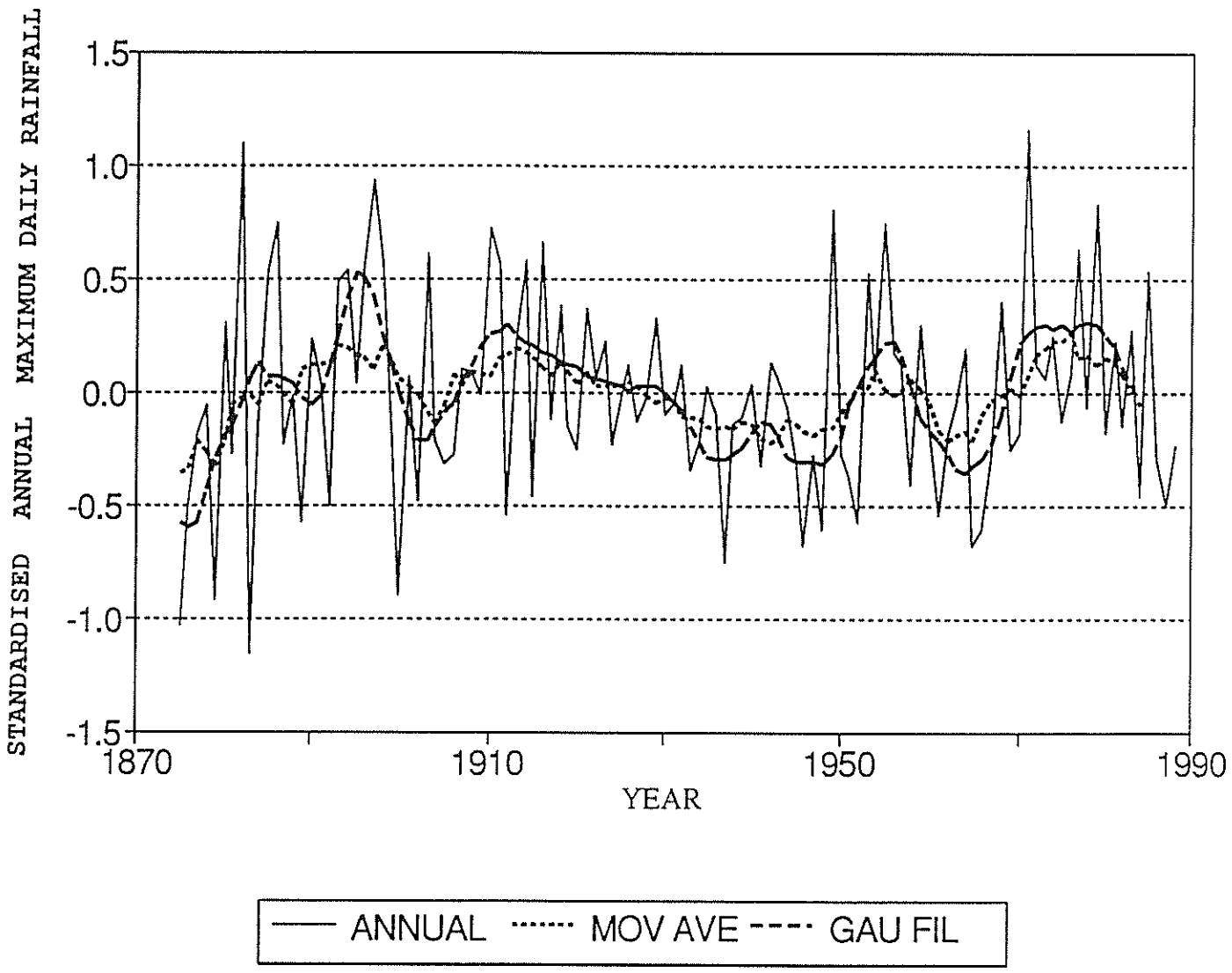


Fig D1. Plot of annual maximum daily rainfall time series with 11 year moving average and 11 point Gaussian filter for summer maximum daily rainfall - tropical region.

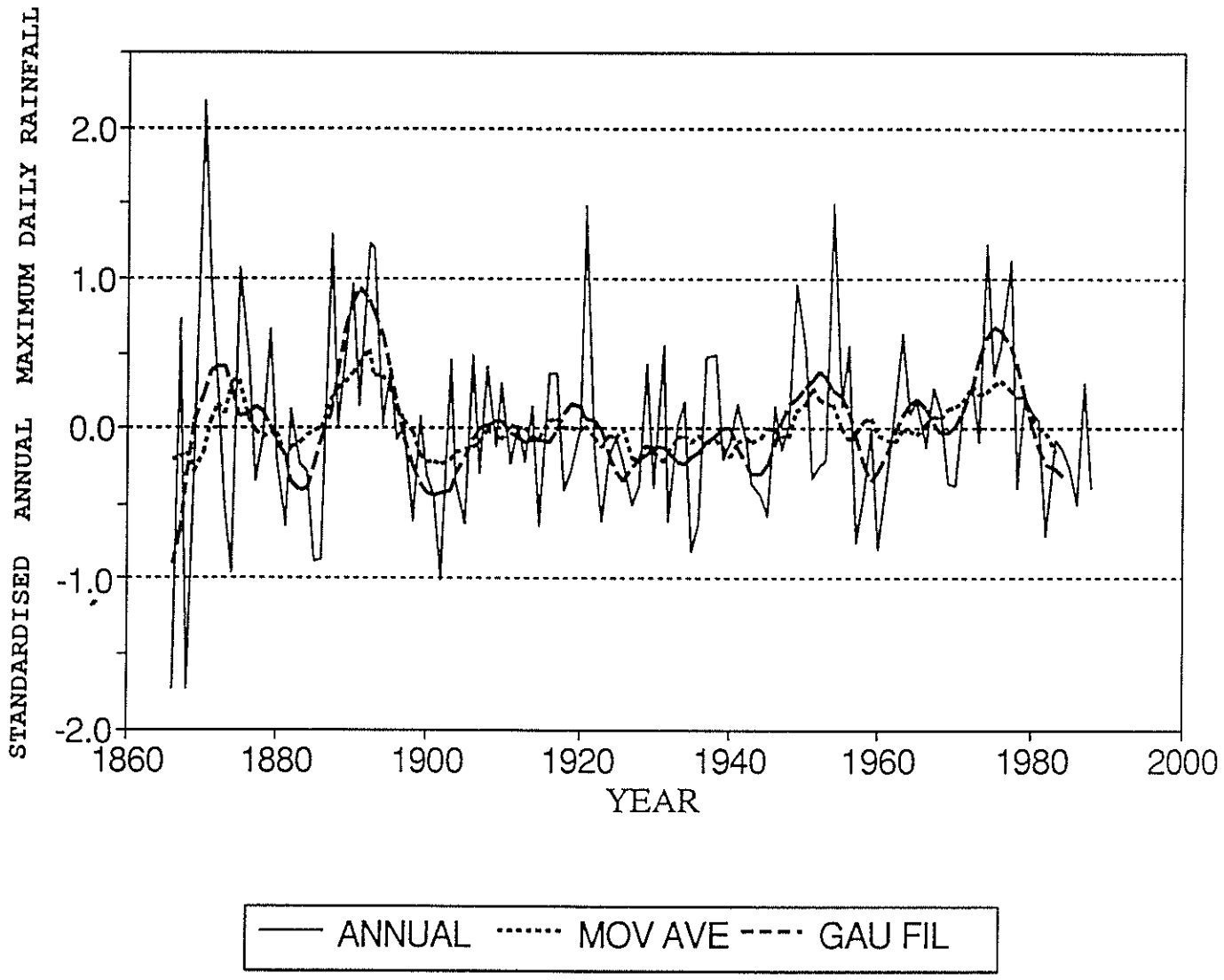


Fig D2. Plot of annual maximum daily rainfall time series with 11 year moving average and 11 point Gaussian filter for summer maximum daily rainfall - sub-tropical region.

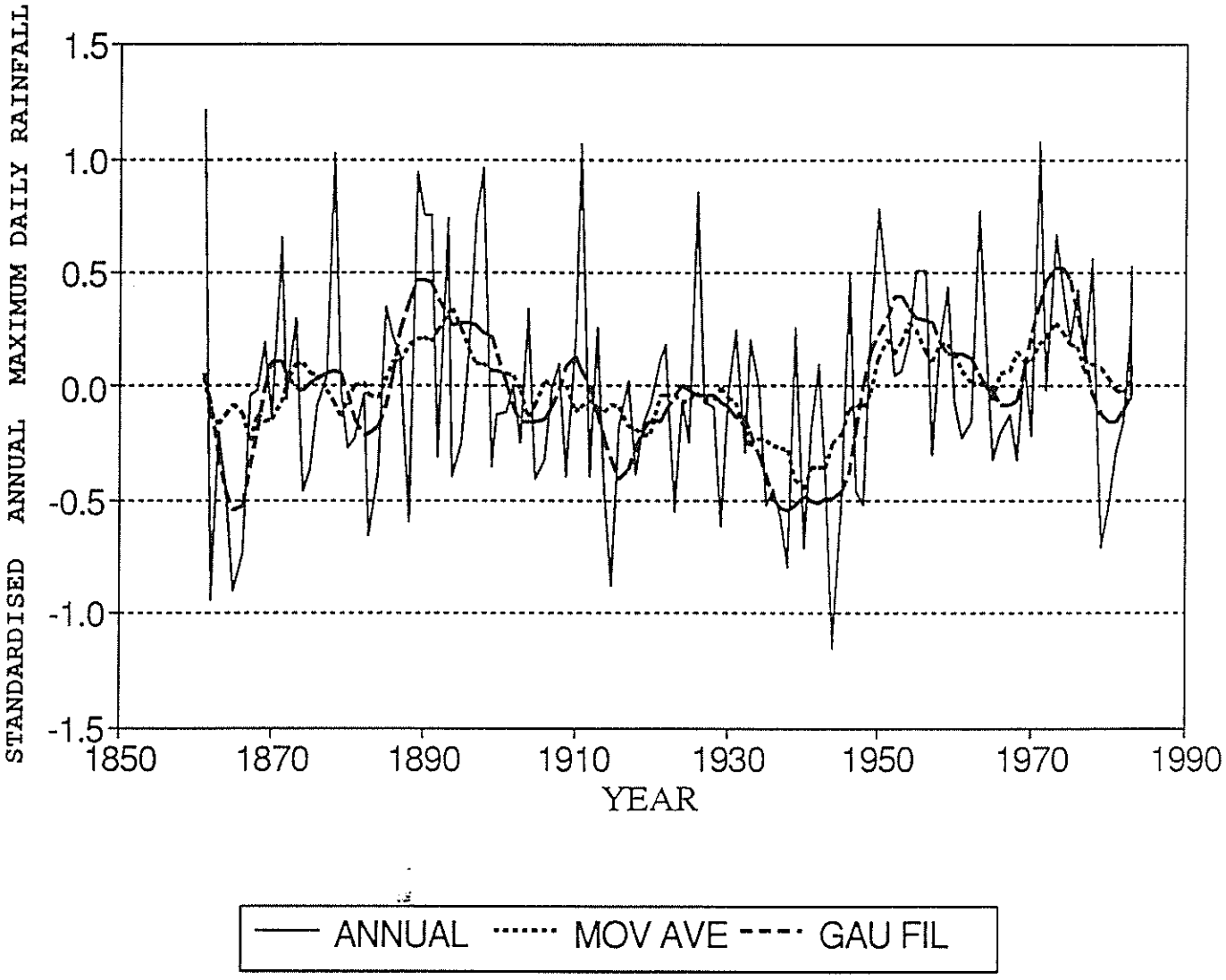


Fig D3. Plot of annual maximum daily rainfall time series with 11 year moving average and 11 point Gaussian filter for uniform maximum daily rainfall - temperate region.

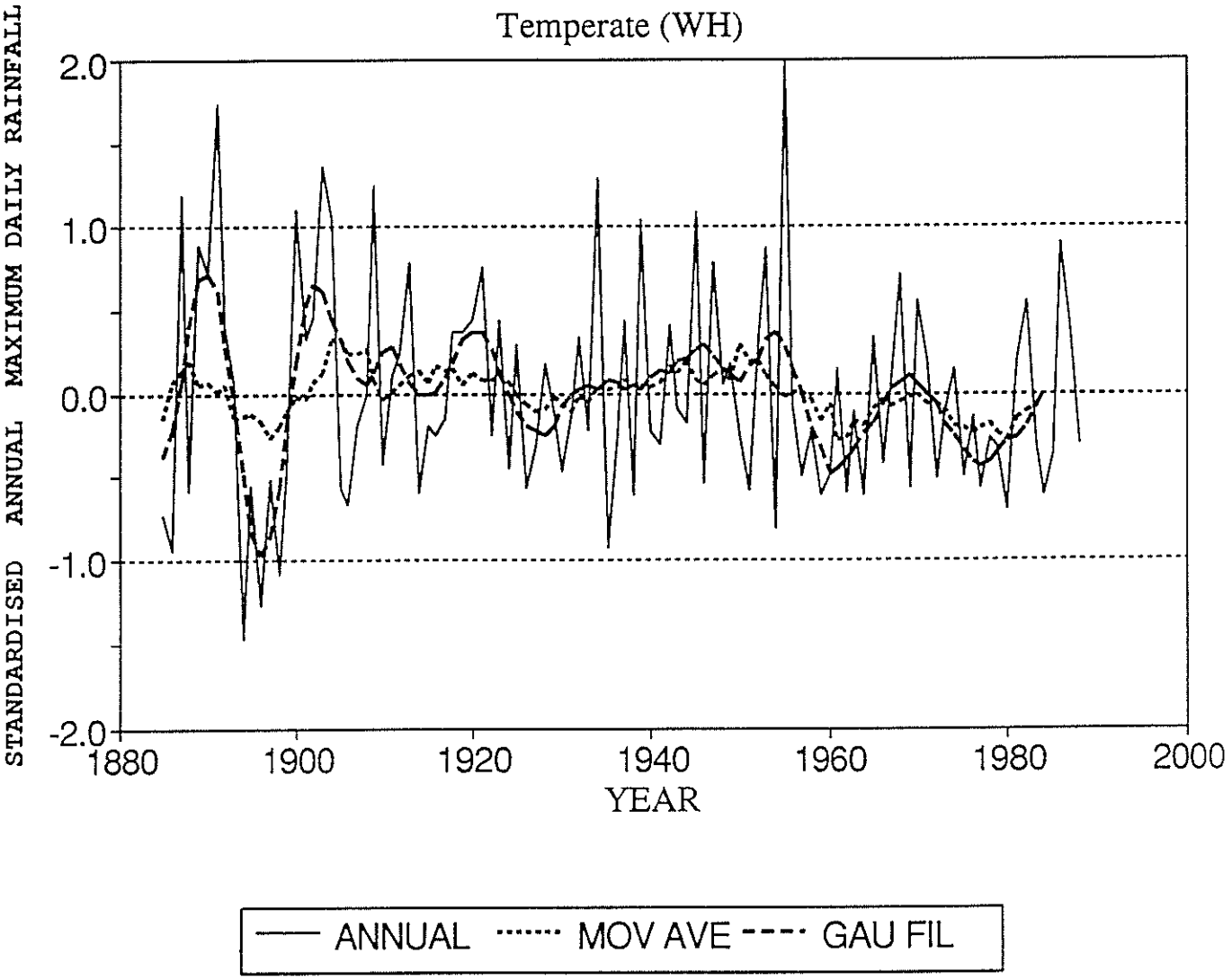


Fig D6. Plot of annual maximum daily rainfall time series with 11 year moving average and 11 point Gaussian filter for winter maximum daily rainfall - temperate region.

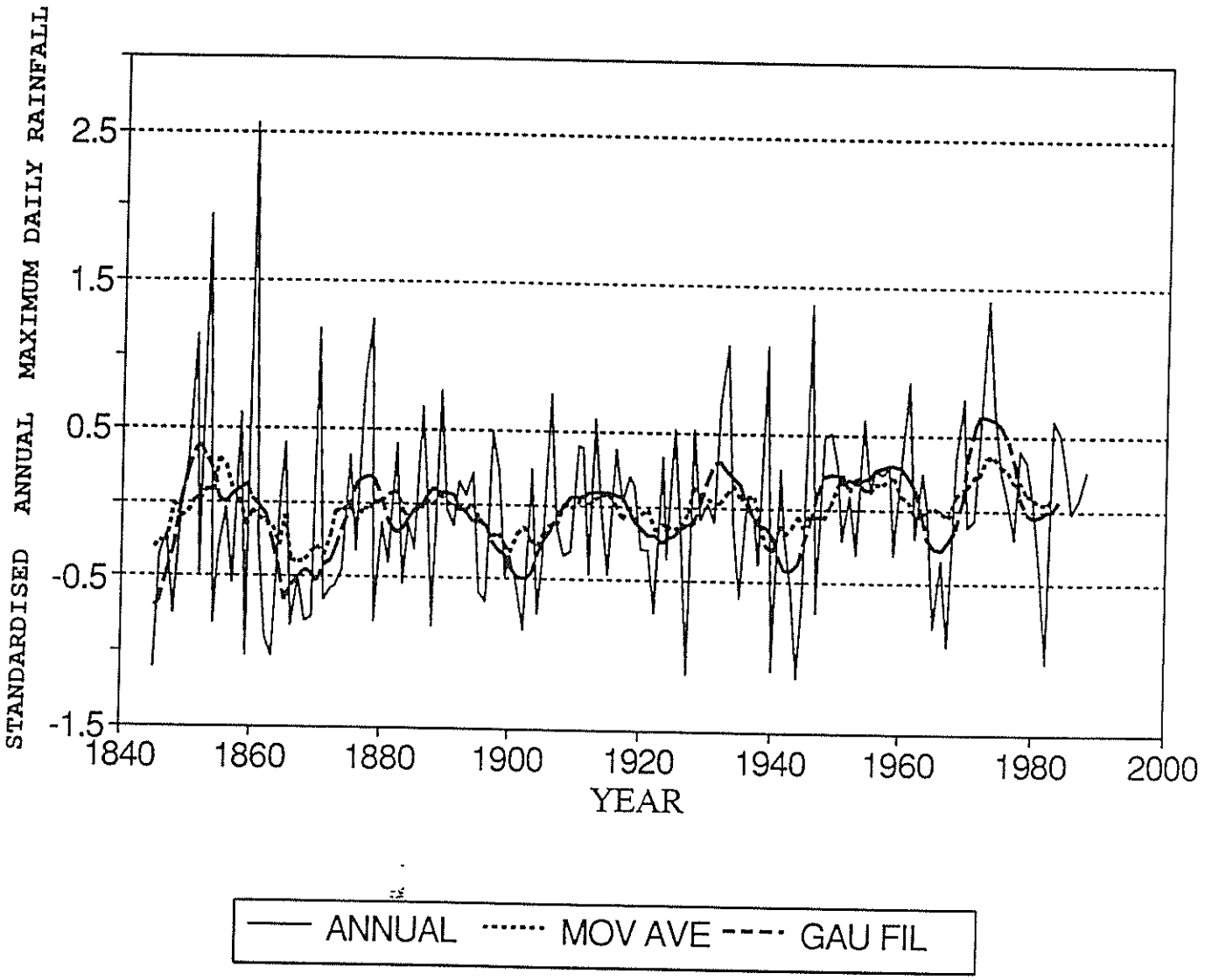


Fig D7. Plot of annual maximum daily rainfall time series with 11 year moving average and 11 point Gaussian filter for winter maximum daily rainfall - temperate region.

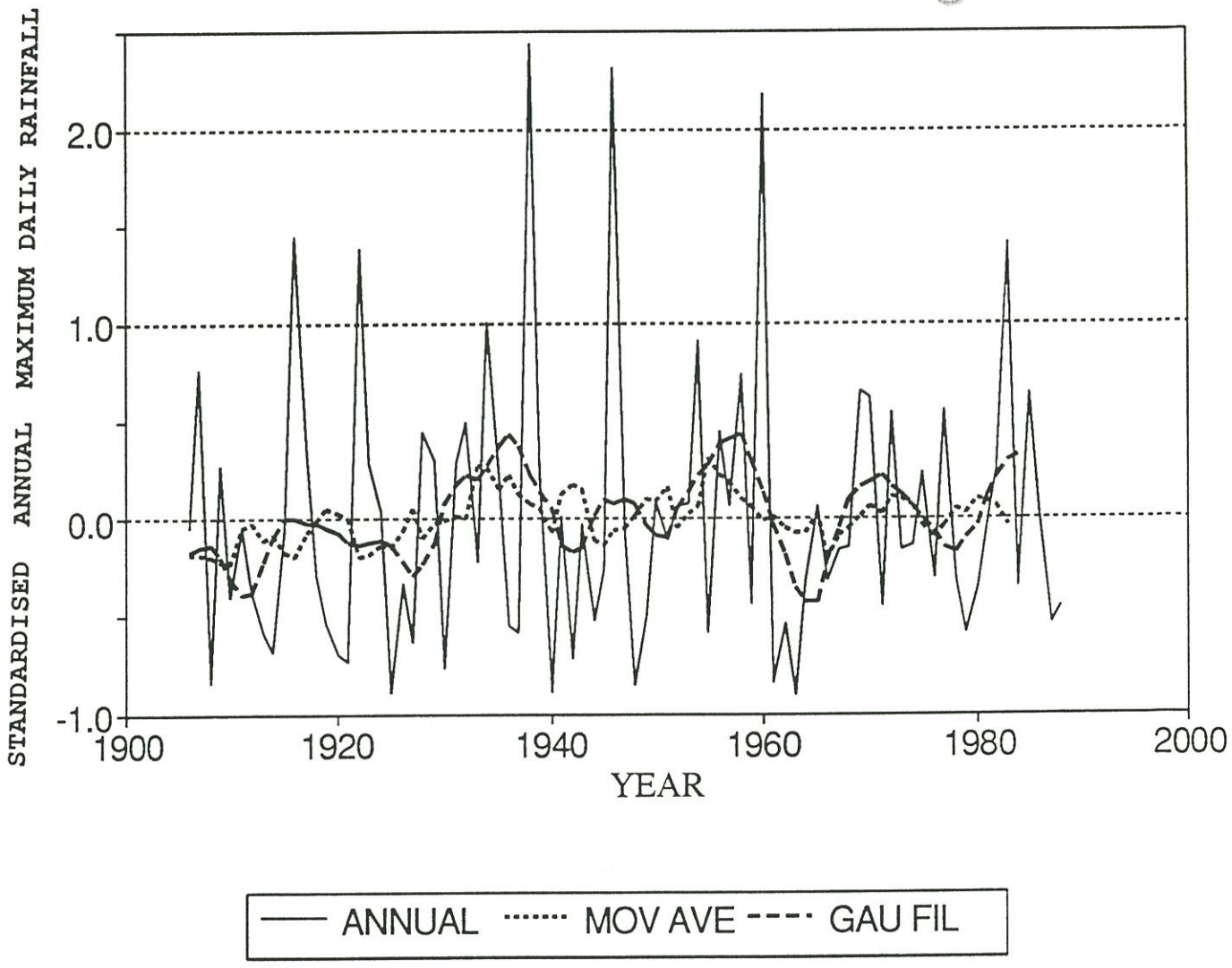


Fig D8. Plot of annual maximum daily rainfall time series with 11 year moving average and 11 point Gaussian filter for winter maximum daily rainfall - Tasmania.